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CONTENTS.

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GENERAL ASTRONOMY.

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ARE THE COMETS, OR ANY PORTION OF THEM, EVER REPELLED BY THE SUN?*

GEORGE W. COAKLEY.†

This question may be determined by considering the relative forms of orbits, with reference to a center of force, described under the influence of attraction towards such center, or of repulsion from it.

In the "Text-Book of General Astronomy for Colleges and Scientific Schools," by Professor Charles A. Young, of Princeton, Articles 402, 403, etc., there is a demonstration of the fact that a body, acted upon by a center of force, whether of attraction or repulsion, and varying according to any and all laws with regard to the distance from that center, will always describe equal areas in equal times, and will also be confined to a single plane. But the contrast in the forms of the orbit, between the case of attraction towards the center of force, and that of repulsion from it, is not sufficiently noticed in that demonstration, nor completely exhibited by the limited figure employed. The following figures are, therefore, intended to emphasize this contrast of form in the two kinds of orbit, without repeating what Professor Young has sufficiently proved with regard to the equality of areas, and the identity of the orbit's plane. In Fig. I. let *S* represent the Sun, or any other center of attraction, varying according to any law whatever as to mass and distance. Let *AB* represent the direction and velocity of a body, or the space that would be described uniformly in the unit of time, any arbitrary unit. If the body is not affected by any external force, it would proceed in the next unit of time to describe the equal distance *BB′* in the same direction. But if *S* now exerts an attractive force which would alone carry the body to the distance *BB″* towards *S* in this second unit of time, then the body will describe the diagonal *BC* of the parallelogram *B′B″*. If no further action of *S* upon the body is exerted, then at the end of the third unit of time it will

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describe, in the direction *BCC′* a distance *CC′* equal to *BC*. But if the center of force at *S* should, in this third unit of time, cause the body to describe the distance *CC″*, when acting alone, then the body will describe, in this time, the diagonal *CD* of the parallelogram *C′C″*. In like manner the diagonals *DE*, *EF*, etc., would be described in the fourth, fifth, etc., units of time.

It is clear that these successive diagonals will form a polygonal line *enclosing* the center of attraction, *S*, within it. This line will be *concave* towards the center of force, in every possible case of attraction.

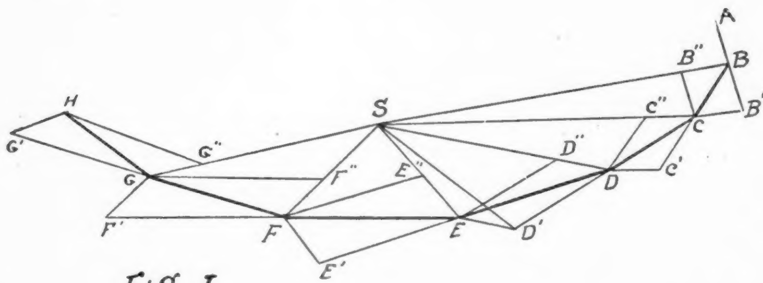


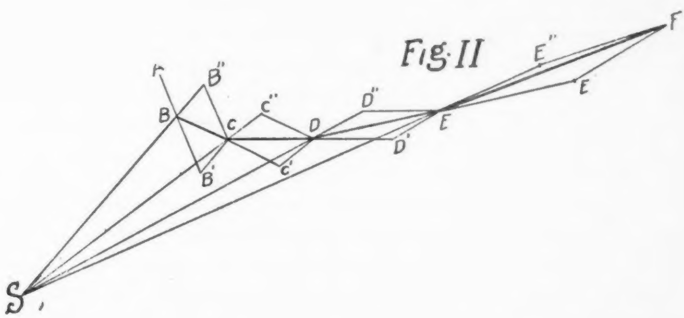
Fig. I.

If now the unit of time be chosen, successively smaller and smaller, the successive impulses of attraction towards *S* will be more and more frequent, the sides of the polygonal line becoming constantly shorter. Finally, if the intervals of time become infinitesimal, the sides of the polygonal line will also be infinitesimal, and it will melt into a continuous curve, when the attractive force is continuous, the curve being, if we choose to consider it so, the *limit* of the polygonal line; and the continuous action of *S*, the limit of its successively decreasing impulses. This curve, it is evident, is in all cases of attraction, *concave towards the center of force*.

In Fig. II. let *S* be any center of repulsion, and let *AB* represent the distance and direction described by a body in any unit of time when not acted on by any external force. Then in the next unit of time it would, under similar circumstances, describe, in the same direction, an equal distance *BB′*. But if, at the beginning of this second unit of time, the body were repelled from *S*, in the direction *SBB″*, to the distance *BB″*, in the unit of time under the action of *S* alone, then the body would describe the diagonal *BC* of the parallelogram *B′B″*.

In a similar manner the body, in the third, fourth, etc., units of time, would describe the diagonals *CD, DE*, etc., of the parallelograms *C′C″*, *D′D″* etc.

Hence the polygonal line *ABCDE*, would be described, having the center of force, in all cases of repulsion, on the outside, or the *convex side* of the polygonal line. It is evident also, that when the intervals of time are made infinitesimal, the sides of the polygonal line become also infinitesimal, or melt into a continuous curve, still convex to the center of repulsion.



In the case of attraction we also know that the concave curve may become re-entrant, as a circle, ellipse, or other closed curve, with the center of force somewhere within the enclosure; or it may be a curve like the parabola, with branches on each side of its axis, proceeding to infinity and ultimately practically parallel; or, again, it may be a curve, like the hyperbola, with branches on each side of its axis diverging always towards infinity. But in every such case of attraction, the center of force is *within* the curve.

In the case of repulsion, however, no closed curve is possible. It is always either an exact hyperbola, of the conic sections, or some curve, more or less resembling the hyperbola in form, with the center of force always exterior to the curve.

As illustrations of these general laws of attraction and repulsion with regard to any center of force, and the forms of the orbits described under their influence, it may be permitted to state some of the results obtained by assuming certain particular laws of attraction and of repulsion. It is well known that the Newtonion law of attraction, applied to the Sun, and any smaller mass, may give either a circular orbit, with the Sun at the center, or an ellipse of any excentricity, with the Sun at one

of the foci, or a parabola, or hyperbola, with the Sun at a focus, *within the orbit.*

The planetary orbits, as well as some of the orbits of comets, illustrate the closed, or elliptical forms, and some of the cometary orbits may possibly illustrate also the parabolic and hyperbolic forms, but in all these cases the orbits are concave to the center of force.

In a preceding number of THE SIDEREAL MESSENGER, No. 97, August, 1891, will be found the proof that if the Sun be regarded as a center of repulsion, whose intensity is directly as the sum of the masses, and inversely as the square of the distance, or the Newtonian law, except that attraction is replaced by repulsion, then the only orbit possible with this law is the hyperbola of the conic sections, but the Sun occupying the focus *external* to the hyperbolic branch described. Hence the orbit, in this case, is convex to the Sun, or to the center of force.

By a process entirely similar to that employed in that article of THE MESSENGER, the cases both of attraction and repulsion when the intensity of the force varied directly as the mass, and also directly as the distance from the Sun, were investigated. It was found, as was well known previously, that in the case of attraction according to this law, the orbit is an ellipse with the Sun *at the center*, instead of at one of the foci, and that the time of a revolution is constant for ellipses of all sizes.

It was also found that in the case of repulsion by the Sun, directly as the mass, and directly as the distance, the orbit is the conic hyperbola, with the Sun also at the hyperbola's center, instead of at either focus; and hence the Sun is outside the orbit in this case, or the orbit is convex to the center of force. This is evident since the hyperbola's center lies midway between the vertices of its two opposite branches.

The next two cases, one of attraction, the other of repulsion, investigated in a similar manner, were on the supposition that the laws of attraction and repulsion respectively were directly as the mass and inversely as the *cube* of the distance.

The equation of the orbit found, in the case of attraction according to this law, is

$$r = \frac{a}{\cos(n\theta)},$$

where $r =$ the radius-vector, $a =$ the perihelion distance, $\theta =$ the variable angle made by r with the axis, which is the line from the Sun to the perihelion point, and $n < 1$ in the case of attraction.

On projecting the curve, with any value of $n < 1$, as $n = \frac{1}{2}$ for example, it is readily seen to be concave towards the Sun.

Curiously enough, in the case of *repulsion*, according to this law the equation of the orbit is found to be of the same form, viz:

$$r = \frac{a}{\cos(n\theta)}$$

with similar meanings of r, a and θ, but with $n > 1$. This curve also, being projected, with any value of $n > 1$, gives a curve always convex to the Sun. In fact the curve representing the Sun's attraction according to the inverse cube of the distance, resembles somewhat a parabola with infinite parallel branches proceeding from the perihelion point, though it is not the ordinary parabola of the conic sections; while the curve representing the Sun's repulsion with the same law resembles the hyperbola, with its constantly diverging arms, though this also is not the ordinary hyperbola of the conic sections.

Having now demonstrated, and illustrated in several cases the important laws, that every orbit relative to the Sun as a center of *attraction* is necessarily *concave* to that centre of force; and secondly, that every orbit relative to the Sun as a centre of *repulsion* is necessarily *convex* to the same centre of force; it remains to apply these laws to the well known forms of the cometary orbits in order to answer the question at the head of this paper. Of course no astronomer will maintain that the nucleus and head of a comet that has just passed around the perihelion point of its elliptical, parabolic or even hyperbolic orbit, with the Sun at the focus of the orbit, within the curve, has not been subject to the Sun's *attraction* at every point of its path. The nucleus and head, it will be granted, have described a curve wholly *concave* towards the Sun. Not only so, but every point of its path has been determined, and can be computed solely by the great Newtonian law of the Sun's attraction. Any variation of this law, in kind, or in amount, would determine a wholly different curve. It is well known that after three geocentric right ascensions and declinations of the nucleus of a comet have been observed with considerable accuracy, even if they are only a few days apart, an astronomer can compute the path which the comet will travel among the fixed stars, and thus have an ephemeris, or catalogue of its daily position, by which he can follow it as long as the telescope will show it. He points his telescope each night upon the place marked in his ephemeris, and which places have been computed solely on the supposition that Newton's law of

attraction is invariable. Had there been any defect in that law it would be impossible to find the comet on pointing the telescope to the place marked in the ephemeris. For the comet would have departed from the computed orbit, and pursued a quite different path, in obedience to the new law of attraction, or repulsion. It is presumed therefore that all intelligent astronomers will agree that Newton's law of attraction between the Sun, and the nucleus and head of the comet, has been implicitly obeyed by these parts of the comet, from its first distant appearance in the telescope to its perihelion passage, and afterwards until it has disappeared beyond the reach of the telescope.

Moreover, when a comet is first seen at the greatest distance at which it may be discovered by the telescope it usually presents a round, nearly circular disk, and the whole comet then moves down towards its perihelion, just as a planet would do if describing an orbit with the same excentricity. There is at that time no sign or suspicion of any repulsion by the Sun of any part of the comet. But on a nearer approach to the Sun, while running down to its perihelion, the phenomenon of a train, or so-called tail, is developed, generally directed away from the Sun. It is principally to account for this phenomenon that the theory of repulsion by the Sun, on at least a portion of the cometary matter, has been proposed. If this phenomenon can be explained in accordance with known laws, there would seem to be no sound scientific reason for invoking any repulsion on the part of the Sun, especially as all the other astronomical forces are the *attractions* arising from Newton's law of Gravitation.

For the sake of argument however, let it be granted that the matter forming the train projected behind it, while the comet is running down to its perihelion, is repelled by the Sun, instead of being attracted. What would be the consequence? The nucleus and head of the comet are being accelerated at every moment in their journey towards perihelion. But these repelled particles of the train are not only not being accelerated in the same direction, because not attracted, but are being retarded constantly by the Sun's repelling force. They must, therefore, become wholly detached from the comet in a short time after the beginning of the solar repulsion. Besides, they must begin at once to move on a curve *convex* towards the Sun, and to describe a path that would give them a *wholly different perihelion*, in position and direction, from that of the nucleus and head of the comet. After passing this perihelion of the *convex orbit*, these repelled particles must be driven off by the Sun into infinite outer space, never

again to return to his vicinity by any action he could exert. For to suppose these particles repelled at one time, and at another to be attracted by the Sun, seems entirely too arbitrary to be dignified with the name of science. The particles of the comet's train, thus supposed to be repelled by the Sun, must therefore be considered to have entirely abandoned the solar system. They could by no possibility form parts of those *meteoric ring-systems* regularly revolving around the Sun in closed elliptic orbits, which furnish the various *periodical showers* of shooting-stars. A few of the writer's friends have interposed the following objection to the view just stated, with regard to the dissipation of the repelled particles of the comet's train. It is conceivable, says one, that though these particles are repelled by the Sun, far enough away to form the train, yet they are attracted by the nucleus and head of the comet with sufficient force to be carried along with the head, and thus pass around the comet's perihelion. The answer to this objection is two-fold. First, that must be a singular sort of matter which is at the same time repelled by the Sun, and attracted by the head of the comet, which is itself attracted by the Sun, according to Newton's law. But as this answer may not weigh as much with the repulsion theorist as perhaps it ought, this additional answer may be made:

Consider how small the *mass* of even the largest comet is; generally considered less than $\frac{1}{5000}$ of the earth's mass. Professor Young's statement of the earth's mass, that of the Sun being the unit, is $\frac{1}{331100}$. He also estimates the mass of a comet as about $\frac{1}{100000}$ of the earth's mass. Taking, however, the former estimate, will make the comet's mass less than $\frac{1}{1600000000}$ the Sun's mass. The head of Donati's comet is given as 250,000 miles in diameter by Professor Young. Hence, even most of the nearer positions of the train of this comet were at least as far from its center of gravity as our moon is from the earth. Now it is known that the Sun's attraction on our Moon, at the earth's mean distance from the Sun, is about twice that which the earth exerts on our satellite, at a distance less than one-fourth of a million miles. When, therefore, Donati's comet was as far from the Sun as the earth is, if he attracted these particles of the train with his normal force, that attraction would be at least 10,000 times as great as the attraction of the comet's head for these same particles, and many times greater still for the yet more distant particles of the train. So much for the relative amount of *attraction* by the Sun and by the comet itself on the material forming its train. But in Professor Young's Astronomy, before referred to,

is the statement, Art. 731, that, according to the views of Bredichin, there are three different types of comets' tails, the long, straight rays, as seen in Donati's comet by Professor Bond, "the curved, plume-like train, like the principal tail of Donati's comet," and the "short, stubby brushes violently curved." The trains of the first type are considered to be due to a repulsive action from the Sun, "twelve to fifteen times as great as the gravitational attraction;" the trains of the second type are supposed to be due to a repulsion from 2.2 times gravity to half that amount; those of the third type are due to repulsive force "only a fraction of gravity, from $\frac{1}{10}$ to $\frac{1}{2}$."

It follows, therefore, that, even when the comet is as distant from the Sun as the Earth is, the very smallest of these supposed repulsive forces, $\frac{1}{10}$ that of solar gravity, is still at least 1000 times as great as the comet's attraction for the repelled particles of the train that are only at a comparatively small distance from the head. When, furthermore, the comet runs down to within a short distance of the perihelion point, the inverse square of its diminished distance from the Sun, will greatly increase the ratio of his repulsion to the comet's attraction for these particles. It is therefore quite impossible for any attraction of the comet's nucleus and head upon even the nearer portions of its train, and still less fôr its attraction on the more distant portions, to overcome this enormous repulsion of the Sun for these particles. It is certain, therefore, that they can never pass the comet's perihelion point together with the nucleus and head, nor at any time subsequently on the theory of repulsion; since they must, in such case, move off in an orbit *convex to the Sun.* Hence it follows that all the particles of the comet's nucleus and head that have passed the perihelion of its orbit must be of a different nature from those that were repelled by the Sun previous to that epoch. They must be such particles of the comet as are subject to the Sun's *attraction only*, and not to his *repulsion.* For otherwise, as has been shown, they could never come up to and double the cape of the perihelion. All the particles that were of such a kind as to be subject to the Sun's *repulsion* instead of his *attraction*, must have been *sifted out* by that repulsion, and dissipated forever into outer space. But, strange to say, after the comet's perihelion passage, a new train or tail is developed, usually turned away from the Sun, like the one before perihelion passage. To account for this recourse is had again to the same theory of repulsion. But why should these particles of the comet, which, before coming to perihelion, were not subject

to repulsion, because this would have prevented their passage, be now changed in their allegiance to the Newtonian law? The truth is, a new explanation of the trains or tails of comets must be found, not involving the supposition of any repulsion. The proper consideration of the forms of orbits, necessarily described under any central *repulsive force*, and under a central *attractive force*, demonstrate the absurdity of supposing any portions of a comet to be repelled by the Sun.

There is no question that there is something in the pretty regular turning of a comet's train away from the Sun, both before and after perihelion-passage, that looks very much like repulsion by the Sun of some portions of the cometary matter. But it does not follow from this *appearance* that there is any real repulsion. So also it looks very much as though the Sun rose up every morning from below the eastern horizon, travels along the vault of the heavens, in a western direction, and sets every evening in the west, while the Earth below him stands still. And this view was actually maintained for many ages. But now every one knows that this is only an appearance and not the reality. So also, the heaping up of the waters of the ocean on the side of the Earth opposite to the Moon, looks as though the Moon repelled the waters of the more distant hemisphere, while she attracts those of the nearer hemisphere, and so tends to raise a tide immediately under her, by attraction, and another opposite to her, by repulsion. But astronomers know that there is no repulsion in the case, but only a *difference of attraction* on the Earth as a whole, at its centre, and a greater attraction on the waters of the nearer hemisphere, with a less attraction on the waters of the remote hemisphere. It seems strange that astronomers have not long ago taken the hint from our own *tides*, and applied this same theory of the Sun's *Difference of Attraction* on the nearer and remoter portions of a comet, to explain its *figure of equilibrium*. The *smallness* of a comet's *mass*, the *greatness* of its *volume*, and the *rapid diminution* of its *distance* from the Sun while approaching its perihelion, or its *rapid increase* of *distance* while receding from the same point, are the important factors in this explanation; together with one more point, which is this. The actions of the Moon and Sun on the waters of our globe are small and nearly equal *practically* in the two opposite hemispheres, first because of their great distance from the Earth compared with the diameter of our globe; secondly because of the Earth's comparatively large mass, more than 5000 times that of any comet; and thirdly because of the

nearly constant distances of the two tide-raising forces. On the contrary, the comet's large volume and small mass, and its varying distance from the Sun, conspire to make his tidal disturbance large, and variable with the distance, and largely different from each other on the comet's opposite sides, the one nearer and the other more remote from him.

Regarding the comet, as in the older and truer view, as a mere mass of very rare gas or vapour, the Sun's tidal disturbing force would penetrate, with varying force, to its very centre, when the comet was at its greatest distance. The greater disturbance in the nearer half of the cometary mass, than in the more remote, would tend to transport more of its material to the hemisphere nearest the Sun, and thus transfer the centre of gravity, the nucleus, in that direction. This in turn would give greater power of attraction to the nucleus upon the surface nearest the Sun, and diminish its control on the more remote parts of the comet in the opposite direction. The writer may be permitted to refer to the volumes of the American Association for the Advancement of Science, for his paper "On the Tidal Theory of Comets," presented at Cambridge, Mass., in 1880.

There is a difficulty connected with the passage of a comet, and *its train*, around the perihelion point of the orbit, which still seems to need clearing up. Some of the older writers on the subject usually represented the whole comet, nucleus, head, and train stretching away from the Sun in a straight line, for millions of miles, like a stiff rod, passing around the perihelion point, always in that same relative position, head and nucleus towards the Sun, and the distant train straight out from the perihelion point, and then sweeping around *faster than the head*, so as to get into position *away from the Sun*, after the perihelion passage. But this sort of motion, as pointed out by Sir John Herschel, is a mechanical impossibility. For the parts of the comet nearest the perihelion have necessarily the greater velocity, and those more distant a correspondingly less velocity, the velocity in cometary orbits varying nearly as the inverse square root of the radius-vector. The more modern view seems to be, though it is nowhere very confidently asserted, that the old train, before perihelion-passage, has been entirely dissipated by the Sun's repulsion, and that the train seen after perihelion-passage is a new one, subsequently developed by a new repulsion. The absurdity of this second supposition has perhaps been made plain enough.

On the tidal theory of the forms of comets, the train is behind

the nucleus and head, in time while approaching perihelion, because, being more distant from the Sun, it is moving more slowly, in obedience to the inverse square root of the radius-vector. But it is moving, *as nearly as may be*, along the same orbit pursued by the head. It reaches the perihelion *later* than the head and nucleus. In fact, so great is the increase of *velocity* of the comet's head, when near perihelion that it, as it were, jerks away from and severs entirely its connection with at least the more remote portions of the train.

After perihelion passage of the comet's head, the same tidal perturbation of the comet's figure by the Sun, now at its maximum on account of its least distance, develops the same elongated figure, with the comet's centre of gravity, its nucleus, nearest to the Sun. Some portions of the old ante-perihelion train are never able, though following along the same general orbit, because still *attracted* by the Sun, to overtake the head, nucleus, and new train, that have preceded it in perihelion-passage. Even when the head, or main portion of the comet, has reached the *aphelion* of its elongated ellipse, the portions of the old train left behind have not yet reached that point, and are slowly climbing towards it with retarded motion, while the head has commenced its accelerated motion towards the perihelion once more. Of course the old train can never overtake the head; it is always behind the latter.

At the next perihelion-passage of the comet's head, a new portion of the new ante-perihelion train is similarly detached. Thus there are at least two cloud-like masses of cometary matter, following in the orbit of the comet's head. At the next perihelion-passage there will be a third cloud of cometary particles detached, and so on, after each successive revolution. These cloud-like detached particles will ultimately be distributed along the orbit, over a large arc, or in some cases throughout the entire orbit. These are the meteoric masses, describing elliptical orbits about the Sun, derived from the successive disintegrations of a comet at each passage of its perihelion, and with sometimes one or more comets pursuing the same orbit. In this way the November meteoric bodies, or the August meteoric bodies, and others, may be explained. It is then only requisite that the orbits of these bodies should nearly or quite intersect that of the Earth, to bring about a periodic swarm of shooting stars.

If it be granted, as is most probably the case, that these meteoric masses, are somehow derived from the disintegration of the trains of comets, then it is quite certain that they were never

repelled by the Sun. For these masses revolve in regular ellipses, concave towards the Sun, which occupies the focus of their orbits just as in the case of the planets. The orbits of these bodies, moreover, have been computed by the same Newtonian law of attraction by which the orbits of the other members of the Solar System have been determined. This is perhaps the most positive demonstration that no parts whatever of a comet are repelled by the Sun, but that all are attracted in accordance with the great Newtonian law. No closed curve, like the elliptical orbits of the meteoric masses, could possibly be described under the influence of any repulsive force. If therefore, these meteoric particles are *attracted*, and not *repelled*, as is certainly the case, then no good reason can be assigned why those particles forming even the extreme portions of a comet's train should be repelled by the Sun.

THE EFFECT OF PRESSURE UPON THE TRANSMISSION OF RADIANT ENERGY THROUGH GASEOUS MEDIA.*

SEVERINUS J. CORRIGAN.

Equation (15) shows that the quantity of heat, Q, emitted from unit surface, and transmitted through a gaseous medium is, when the temperature, t_2, of the source of heat, and t_1, that of the enclosing walls are constant, a function of the pressure, P_1; *i. e.*, $Q = \varphi\,(P)$, and it is obvious that, if these temperatures be varied, the pressure remaining constant, the quantity of heat radiated will also be varied, or, in other words that Q will be also a function of t_2 and t_1; *i. e.*, $Q = \varphi(t_2,\ t_1)$; therefore, when both of the temperatures, and also the pressure, vary, the quantity of energy radiated, in unit time, from unit surface will be a function of t_2, t_1 and P, and we can write $Q = \varphi\ (t_2,\ t_1) \,.\, \varphi\ (P)$, (24). The resultant quantity, Q, is, therefore, composed of two components, viz.: $\varphi(t_2\ t_1)$ and $\varphi(P)$. The second, as has been shown, is dependent upon the orbital motion of the atoms composing the molecules of the gas, around a common centre of attraction, in the same manner and according to the same law that governs the motions of the planets around the Sun, and of two suns or stars around their common centre of gravity. Its value is, as has been shown by equation (15), expressed by $\varphi(P) = P^{\frac{1}{4.5}}$.

* Continued from No. 101, page 7.

The first component $\varphi(t_2, t_1)$, due to temperature, can be regarded as indicating a *perturbative* action upon the *orbital* motion represented by the second factor of the second member of equation (24), or to a vibratory movement of each system of atoms, *i. e.*, each molecule, in a *longitudinal* direction, this motion being due to an impulse emanating from those vibrating particles of the "source of heat" that are in contact with the gaseous medium, *i. e.*, the surface particles. For the explicit value of the first function I have taken the following:

$$\varphi(t_2, t_1) = Ca^{t_1}(a^{t_2-t_1} - 1),$$

which is based upon Dulong and Petit's well known empirical formula, and in which C is a constant depending upon the nature of the radiating surface, while, a is a constant having for its value 1.0051 when the temperatures are measured according to Fahrenheit's scale. It differs from Dulong and Petit's value which is 1.0043, but their formula was deduced from experiments upon a body heated to less than 450 degrees Fahr., while, in the cases which I have investigated, the temperature exceeded 2100 degrees.

The value, 1.0051, I have deduced from some of Professor Draper's investigations upon the radiation of light from bodies at temperatures of from 1900 to 2600 degrees Fahr.

The value of C for one square inch of polished copper is, approximately, .00002647 of a thermal unit, *i. e.*, of a pound-degree Fahrenheit, per second. Its value for other substances can also be determined experimentally.

The quantity of energy radiated from a heated body, under varying conditions of temperature and pressure, can, therefore, be expressed by the following equation:

$$Q = \varphi(t_2, t_1) . \varphi(P) = Ca^{t_1}(a^{t_1-t_2} - 1) . P^{\frac{1}{4.5}} \qquad (25).$$

That is, if we know the quantity of heat or energy radiated, in unit time, from unit surface of a "source of heat" at a given temperature, t_2, the temperature, t_1, of the enclosing walls being also known, and the enclosed gas being under a given pressure, P, we can find by means of equation (25), the quantity radiated at any other temperatures and pressures. I have used this equation for the purpose of obtaining the absolute quantity of energy radiated in unit time, from the filament of a 16 candle-power incandescent electric lamp in which the pressure of the enclosed air was reduced to $\frac{1}{1000000}$ of the normal atmospheric pressure, and the result, in units of electric energy, *i. e.*, in volt-amperes, or watts, or in equivalent thermal units, or in units of energy, *i. e.*, either ergs, or horse-

power, is almost exactly the same as those obtained by many tests made by several electric-lighting companies. For instance, the glossy metal-like surface of the filament of the latest 16 candle-power "Edison" lamp radiates 54 volt-amperes, or watts, of electrical energy, equivalent to .054 of a thermal unit, or .072 of a unit of electrical horse-power. Taking the temperature of the filament at 2100 degrees Fahrenheit, which is, very nearly, the temperature of *perfectly white* light, the temperature of the glass bulb at 150 degrees, and the pressure of the enclosed air at $\frac{1}{1000000}$ of the normal atmospheric pressure of 30 inches of mercury, equation (25) will give, as the quantity radiated, 55.8 volt-amperes, or watts, *i. e.*, .0558 of a thermal unit, or .075 of a unit of electrical horse-power; a very close agreement between the results of actual practice and those of theory.

Therefore I think that the validity of equation (25) and of all the preceding ones through which they have been derived, and of all the principles on which they are based, is established.

Any statement purporting to furnish an absolutely true, complete and accurate explanation of all the known phenomena of "radiation," would be, I think, premature and unwarranted, and if such statement could be properly made, it would require far more space than could be devoted to it in ASTRONOMY AND ASTRO-PHYSICS, or in any other publication whose province is the same. But the existence of an *orbital* motion of the atoms of a gas, and also of a longitudinal vibration of the system of atoms or the molecules, is, I think, established. The combination of a rotational movement with a longitudinal one, *i. e.*, of both a *transverse* and a *longitudinal* vibration of the energy-bearing or transmitting molecules furnishes, probably, the key to certain phenomena of "radiation" which have been heretofore not clearly explicable. In "radiation" there is probably no transference of matter, only motion being propagated, and the only molecules that need be considered in this connection are those which are in contact with the surface of the radiating and also of the receiving body.

The resultant path of the revolving atoms can be represented when the velocity in the longitudinal direction is much greater than the orbital velocity, by a wave-like reversed curve, for one-half of the duration of the complete longitudinal vibration, and by a like curve running in the opposite direction, for the other half. Could the body to which heat is radiated be a *perfect* ab sorber, there would be a reversed curve, or a wave in only one direction as shown in Fig. 1, in which S represents the "source of

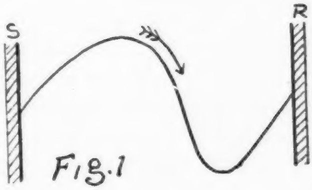


Fig. 1

heat," and R the receiver or absorber. In this case there will be a curve in only one direction, indicated by the arrow, because the motion of the revolving atoms will be destroyed or rather be wholly given up to atoms composing the receiver, R, so that there can be no return curve or wave. In the case where the receiver cannot absorb heat, *i. e.*, where it is a perfect reflector, the action is represented in Fig. 2; the longitudinal vibration being complete, there is a return curve or wave as shown by the arrows; the figure represents the fact that as much heat is sent back or *reflected* to the "source" as has been radiated from it, or, in other words, that the source has lost no heat.

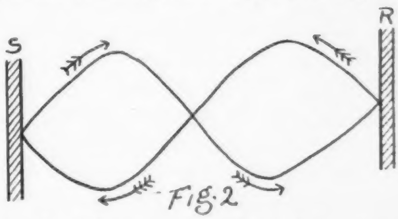


Fig. 2

The molecules which have given up their motion are replaced by others more active, thus producing the phenomenon called "*convection.*" In the above diagrams only one wave is represented moving in the same direction, but the number is dependent upon both the orbital and the longitudinal velocities, and it is really almost inconceivably great.

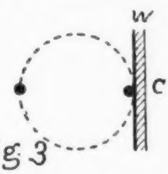


Fig. 3

Could there be a condition in which a mass of gas, such as the atmosphere, would not be acted upon by "radiations" from "sources of heat," the condition would be represented by Fig. 3, in which the atoms revolving in the orbit represented by the circle make simple contact with the wall W, at only one point, C, and the amount of impact is infinitely small. But if, as is always the case, the molecules or systems of revolving atoms are given a vibratory motion in a longitudinal direction, by an impulse imparted to them by the molecules of some heated body, the condition would be represented by Fig. 4, in which S represents the radiating surface and R the surface of the receiver.

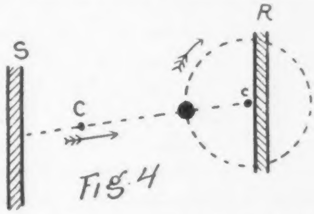


Fig. 4

We can see that, by the shifting of the system of revolving atoms longitudinally from S to R, the centre, C, moving as indicated by the arrow, the atom would make more than a simple contact with the receiving surface, R, and that the latter would, in fact, receive the full force of the impact and be heated thereby.

R

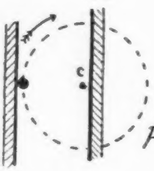


Fig. 5

Fig. 5 conveys the idea that the same effect that is shown in Fig. 4, *i. e.*, the heating of a receiving body, can be produced even if there be no shifting of the system of atoms, or the molecule longitudinally; in other words, if there be no body radiating heat, the effect being produced by the moving of the receiving surface, R, to the left, the centre of the system, or C, remaining stationary. It will be seen that in this case, as in the former, the atom can make full impact upon R and heat it.

This is only one way of expressing the well known fact that *compression* will generate heat. The heating of meteoric masses is a notable case in point; the meteors, rushing with a very great velocity, into our atmosphere, compress the molecules thereof, and the revolving atoms composing these molecules, beat against the surfaces of the meteors, heating these bodies to incandescence.

It is neither impossible nor improbable that the two revolving atoms of each system are in a state of polarity, one positive and the other negative, thus being mutually attracted by reason of their polarity but kept apart by the "centrifugal force" due to their *orbital* revolution, and, under this hypothesis, each system can be regarded as a little magnet. The property, possessed by a magnet, of generating or inducing electrical currents when moved toward or from a conducting coil, is well known, and the greater the velocity of the approach and the recession, the greater will be the current. Therefore, if we regard the retina as representing the coil in which currents are induced, and each system of polarized atoms as the magnet, the approach and recession of the system to and from the retina, may generate therein molecular disturbance which, being conveyed, by the optic nerve, to the brain, produces therein that sensation which is called "light." "Heat" appears to be a purely *mechanical* effect due to the impact of the revolving atoms upon those of the receiving body and, as has been shown above, it is a function of the *orbital* velocity, *i. e.*, its amount depends not only upon the temperature of the "source" but also upon the pressure of the trans-

mitting gaseous mass, or in other words upon the second factor of the second member of equation (25). But the intensity of "light" does not seem to vary with the pressure, but only with the temperature of the "source," it appears to be, particularly, a function of the first factor of the right hand member of equation (25), that is, it seems to depend principally upon the rapidity of the vibrations of each system of revolving polarized atoms or magnets, in a longitudinal direction.

The opinion of the late Professor J. Clerk Maxwell, that "light" is an electro-magnetic phenomenon is well known, and is held by many other physicists.

Of the *absolute* nature of the polar forces we can, probably, learn nothing; like "gravity" or any other force, we can know them only by the effects which they cause; we are not debarred from advancing a hypothesis as to their existence and probable effects, but, for the establishment of the truth of such hypothesis we must depend solely on the agreement between the propositions thereof, and the facts derived from observation of the phenomena of "radiation."

It should be noted that, in the theory which I have above advanced, the so-called molecular forces which generate heat, and the other forms of energy which are regarded as due to the motion of the infinitesimal particles of matter, are considered as producing a vibration of the *atoms* which constitute the molecule, as well as a vibratory movement of the *molecule* itself, which latter vibration seems to have been the only one heretofore regarded. According to my theory the simplest form of molecule would be one composed of only two atoms revolving in one plane (the orbit being a circle for instance) but the number of component atoms may be indefinitely great and the number of planes or orbits in which they move may be likewise indefinite, but there must be a common focus around which these atoms, the components of the molecule, revolve.

If we regard the orbit as a circle (which can be done, since, whatever may be the normal orbit, the pressure upon the gaseous mass, due to gravity, must tend to constrain the orbit to, at least, an approximately circular form), we can conceive of any number of such circular orbits lying in all planes throughout the whole 360 degrees of a circle, but having a common focus or centre; we can also conceive of the existence of an indefinitely great number of sets of two atoms revolving in each plane; therefore, according to this view, a molecule would be a spherical shell composed of an indefinitely great number of revolving

atoms moving around a focus within the shell, and, since each orbit or each system of atoms is subject to change under the action of extraneous forces, expanding when the linear velocity in the orbit is increased by an impulse from the moving atoms of other molecules, or by any other means, and contracting when said velocity is decreased by impact against the atoms of neighboring molecules or otherwise, a mass composed of molecules so constituted would possess those properties which the phenomena of "radiation" seem to indicate as indispensable attributes of a perfect transmitting medium.

By thus considering each molecule as composed of separate bodies revolving around a common focus, Dalton's law, which asserts that "in a mixture of different gases, when there is equilibrium, each gas behaves as a vacuum to all the rest," is clearly explicable, because, according to this view, there is sufficient room for the co-existence and the motion of the atoms composing the molecules of each gas, around their respective foci.

The diagrams given above are intended to convey only a general idea of the action of the revolving atoms producing the phenomena of "radiation," and a more specific statement in regard to the nature of the atomic movements and orbits will now be set forth.

We can conceive that the linear velocity of an atom moving, when the gaseous mass is in equilibrium, in an approximately circular orbit, as augmented, either by impact from the vibrating particles of a source of heat," or by compression; and we can determine the nature and amount of the change effected in the elements by such an augmentation of the linear velocity. To do so we need only to consider the simple and well known mathematical relations which exist between the elements of any orbit described by a body subject to the action of a centripetal force which varies inversely as the square of the distance; it is plain that such an orbit must be one of the "conic sections," and the atomic orbits are not exceptions.

The equations which express the relations between the elements of any orbit are the following:

$$p = \frac{V^2 r^2 \sin^2 \psi}{k}, \qquad (a)$$

$$a = \frac{k}{\frac{2k}{r} - V^2} \qquad (b)$$

$$e = \sqrt{1 - \frac{p}{a}} \qquad (c)$$

$$q = \frac{p}{1+e} \qquad (d)$$

in which V, represents the linear velocity of the body, r, its radius-vector, ψ, the angle between the radius-vector and a tangent to the orbit at the extremity of said radius, p, the semi-parameter, a, the semi-transverse axis, e, the eccentricity, and q, the shortest distance, of the moving body from the focus, while k, represents the unit of attractive force which, for our purpose, can be regarded simply as unity, as relative values only are to be considered. The angle, ψ, is, in the case of a circular orbit, always a right angle, but if we conceive the moving body to receive an impulse from without, not only will the linear velocity be augmented but the direction of the motion or the angle ψ, will also be changed. If V represent the linear velocity in the circular orbit, and V_1 the velocity (at a right angle to the former) imparted by the impact of an extraneous body, the angle, ψ, and the resultant velocity, V_2, will be found from the equations:

$\tan \psi = \frac{V}{V_1}$, and $V_2 = \frac{V}{\sin \psi}$; the value of V_2, so found, is to be used for V in the equations (a) and (b).

A numerical example may serve to elucidate the matter: if we consider only relative values we may take V, or the linear velocity in the circular orbit, and also the other variable elements as each equal to unity; if we now suppose a velocity V_1, equal to V, or to 1, to be imparted to the revolving atom by an impact from without, the angle, ψ, will become equal to 45°, and the resultant, V_2, will have the value 1.414+; then, from the first four equations, we will find that the semi-parameter, p, will be equal to 1, the semi-transverse axis to ∞, the eccentricity to 1, and the nearest approach to the focus, 0.5; in other words, by such increase of velocity, the orbit will become a parabola; for a less augmentation of the linear velocity, it would have become an ellipse, and for a greater, the orbit would have been changed into a hyperbola, as will appear if other values of V_1 be used.

A graphical illustration may serve to render the matter plainer; in Fig. 6 the circle represents the orbit of equilibrium in which the atom at S revolves, when not acted upon by an extraneous force, around the focus C, the revolution being in the direction of the arrow; if an impulse from outside be given to the atom at S, in the direction indicated by the arrow, this atom will move with increased velocity (in the case we have considered) through the arc of a parabola SQR, and, could the velocity become infinitely great, the atom would move in the

straight line *SCR*, through the focus *C*. Observing Fig. 6, we see that if *R* represent a receiving body, the atom moving in the orbit of equilibrium, or the circle, will not impinge upon the receiver, but that, if the velocity be increased so as to change the orbit into any one of the other "conic sections," it will strike more or less directly against the receiving body, as is indicated by the dotted extensions of *SQR* and *SCR* through the same, and by the impact the receiving body will be heated. Furthermore, since the atom does not move around a much more massive body as is the case with the planets, but around a center of attraction whose position depends upon those of the component atoms, being midway between them when they are of equal mass, the approach of either atom toward the focus must cause a shifting or vibration of the latter; therefore Fig. 6 illustrates more *explicitly* the conditions shown in a *general* manner in Figs. 3, 4 and 5. It also elucidates the cause and *modus operandi* of the expansion of a gas by the action of applied heat, the atomic orbit being enlarged thereby, as is shown by the dotted lines. The action of gravity upon a gaseous mass, like our atmosphere, compresses the molecules so that the atomic orbits are restricted to an approximately circular form, and are not the normal ones due to the masses and original velocities of the component atoms; therefore there must be a tendency to expansion in all such masses. We can, therefore, conclude that, in any case, the expansive force of a gas is not due to any repellent force inherent in the gaseous mass, which is the generally accepted idea, but simply to the *orbital* motion of the atoms under the action of a *centripetal* force which operates like that of gravity. In this paper only *relative* velocities and distances have been considered, but the reader can gain some idea of the *absolute* values of these quantities from the fact that of the vibrations producing a "deep red" light there are, approximately, four hundred millions of millions per second, with a wave length of $\frac{1}{19300000000}$ of an inch. Work, done by a moving body, is proportional to one-half the mass multiplied by the square of the velocity of the body. In the case of the atoms the smallness of their weight is compensated by their enormous velocity.

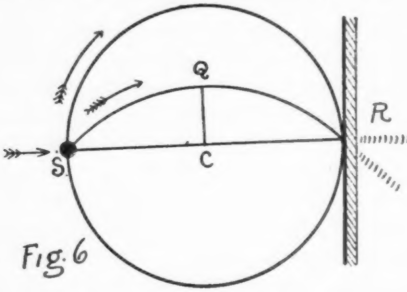


Fig. 6

The conclusions to which the above investigation has led me, can be summarized as follows.

We can conclude, first, that a simple gas is composed of innumerable molecules each of which is formed by two equal atoms, or by some number of atoms which is a multiple of two, the number and grouping defining the chemical characteristics of the gas, and that these atoms are in a state of almost inconceivably rapid revolution around a common centre of attraction lying between them, this motion of revolution being due, as is that of the planetary bodies, to an attractive force which, like that of "gravity," varies inversely as the square of the distance of the bodies from the centre of attraction:

Secondly, that the pressure of a gas upon the walls of a containing vessel (in the case of the "atmosphere" the earth's "force of gravity" can be regarded as the restraining wall), is due to the incessant impact of these revolving atoms upon said walls, and that the pressure aforesaid, is inversely proportional to the 4.5th power of *d*, or the distance apart of the atoms composing the molecules of the gaseous mass, which fact is expressed by the equation, $P = \frac{1}{d^{4.5}}$, whence $d = \frac{1}{P^{\frac{1}{4.5}}}$.

Thirdly, that the quantity of energy, Q, transmitted by and through a gas, from any "source of heat," the temperature of the "source" and of the enclosing walls being constant, varies inversely as d, or directly as the 4.5th root of the pressure, *i. e.*,

$$Q = \frac{1}{d} = P^{\frac{1}{4.5}}$$

Fourthly, that, when the pressure of the gas and also the temperature of the "source of heat," and that of the enclosing walls are constant, the "quantity of heat" Q, transmitted in unit time, will be expressed by the equation, $Q = Ca^{t_1}(a^{t_2-t_1} - 1)$, in which t_2 represents the temperature of the "source" and t_1 that of the enclosing walls, while C is a constant depending upon the surface of the radiating body, and a, is a constant whose numerical value is 1.0051.

Fifthly, that, when both the temperatures and the pressure vary, the quantity of energy or heat, transmitted through the gas, in unit time, can be expressed by the equation

$$Q = Ca^{t_1}(a^{t_2 - t_1} - 1) \, . \, P^{\frac{1}{4.5}}$$

in which the first factor of the second member represents the longitudinal vibration of each system of revolving atoms and the second factor the orbital revolution of these atoms around their

common center of attraction, the resultant being a wave-like motion of said atoms.

Sixthly, that the difference between the specific heat of a gas at constant pressure, and that of a gas at constant volume, is due to the orbital motion of the atoms composing the molecules of the gaseous mass, and that for a perfect gas, the numerical value of the ratio between the specific heats is 1.5; also that the error of Boyle's law, which law is expressed by the equation $P = M$, when the volume is constant, results from neglecting the factor, n, which represents the *orbital* velocity of the revolving atoms, the proper expression being $P = Mn$, when the volume is constant, and furthermore, that the ratio between any two pressures, P_1 and P_2, should be expressed by the equation:

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.5} = \left(\frac{M_1}{M_2}\right)^{1.5}$$

These conclusions also suggest some ideas of a purely speculative nature; for instance, it seems unnecessary to assume the existence of any other than a gaseous medium for the transmission of radiant energy, in other words, there seems to be no necessity for the hypothesis of the existence of a special medium such as "ether." There is no reason to suppose that an absolutely perfect vacuum is ever procurable, for the mass, and therefore the density and the pressure of a gas can be reduced toward infinity, yet there will always be a finite quantity of gaseous matter remaining, and equation (15) shows that the diminution of the quantity of energy transmitted from a given source in a given time is *very, very* far from being proportional to the reduction of pressure or density:

Thus, if a body be emitting a given quantity of heat in air at a normal pressure, it will radiate at a pressure of $\frac{1}{1000000}$th of an atmosphere a quantity equal to $\frac{1}{22}$ of that given out at the normal pressure; while if the reduction be carried to $\frac{1}{1000000000000}$, the quantity will be $\frac{1}{464}$, a very large amount when the enormous reduction of pressure, or density is considered; matter so tenuous could not offer any appreciable resistance to bodies moving through it, and yet it would be capable of transmitting comparatively large quantities of radiant energy. That the relation between the pressure and the quantity of energy or heat radiated, as shown by experiment, follows so closely the law expressed by equation (15) is, I think, conclusive proof that the transmitting medium for radiant energy, or heat, is a purely gaseous one.

The idea is also suggested, that what is called space is not

void, but that it contains gaseous matter in a state of extreme tenuity, the atoms composing this matter being in rapid orbital motion and transmitting energy, thermal, luminous, electrical, and chemical; that from these like atoms are formed all the bodies of the universe, chemical and other characteristics depending upon the grouping and motions of the atoms; we know that all forms of matter can be reduced to the gaseous by the application of a sufficient quantity of heat, or force, and that, therefore, if the original "energy of motion" of the atoms of the gas be lost to them, by transference to the atoms of other bodies or masses, the former will cease to revolve and will become the constituents of *solids*. The revolution of the atoms can, I think, be regarded as the *knowable* fountain-head of all energy, or force, but the answer to the great question, "Whence have sprung these atoms and the forces by which they are impressed, which put them in motion and cause them to revolve?" is known only to Him "without Whom was made nothing that was made." But it does not necessitate an undue strain upon either the imaginative or the reasoning faculty, to conceive that space is filled with these revolving components of the molecules of a gaseous mass; to see, mentally, portions of them parting with their motion or heat, thus, eventually *approaching* the solid state, and forming stars or suns, planets and satellites, the revolution of the atoms being resolved into a like revolution of the resultant bodies around "centres of gravity;" in other words, it is neither difficult nor unreasonable to regard the "nebular hypothesis" as, in the main, true: but, to a knowledge of the absolute nature and origin of matter and force, we cannot hope to attain until the "finite" can comprehend or encompass "The Infinite."

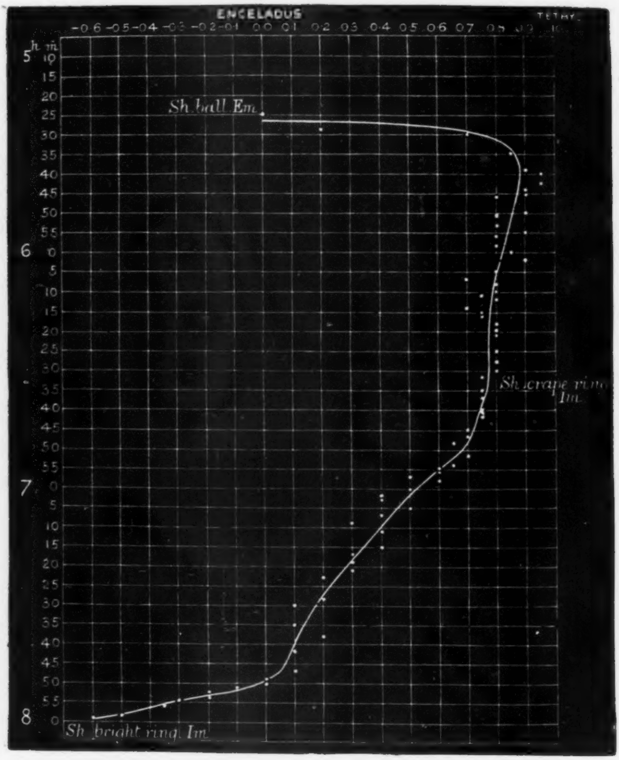
TRANSPARENCY OF THE CRAPE RING OF SATURN, AND OTHER PECULIARITIES AS SHOWN BY THE OBSERVATIONS OF THE ECLIPSE OF JAPETUS ON NOVEMBER 1st, 1889.*

BY E. E. BARNARD.

On the first of November 1889, I observed the eclipse of Japetus in the shadow of the ball and ring system of Saturn with the 12-inch equatorial. These observations were embodied in a paper published in the Monthly Notices of the Royal Astronomical Society for January, 1890.

* Communicated by the author.

In calling attention to this phenomenon in Monthly Notices for June 1889, Mr. Marth says: "The inclination of the orbit of Japetus to the plane of the ring being nearly 14°, while the orbits of the other satellites have inclinations of less than 1°, the rare eclipses of Japetus by the ring system offer the only chance of deciding several questions which may be settled with the help of observed eclipses. No such observation has ever yet been made. Favorably placed observers ought, therefore, to take full advantage of the rare chance they may get on November 1. There will not be another such chance for at least the next sixteen years."



Light Curve* of the Eclipse of Japetus, in the Shadows of the Globe, Crape Ring and Bright Ring of Saturn, 1889 Nov. 1.—*From Monthly Notices, Vol. 50, p. 108.*

One of the problems to be settled at that eclipse was the transparency of the crape ring.

* See *News and Notes* for explanation of the above light curve.

For various reasons, no other observer in the world saw the eclipse of Japetus.

The observations of that eclipse with the 12-inch equatorial have given us more information about the crape ring of Saturn, perhaps, than could possibly have been obtained by a hundred years of ordinary observing.

The night was fine and clear and especially favorable. The planet rose at 12^h 50^m. At first the seeing was only ordinary, but it increased in excellence until in the latter stages of the observations it was superb. By the time the satellite had entered the shadow of the crape ring, the planet had attained a high altitude and was excellently placed for observing.

When Saturn rose at the Lick Observatory, Japetus was already in the shadow of the ball—having passed through the first half of the shadows of the rings. Near the predicted time the satellite re-appeared from the shadow of the ball into the sunlight shining between the ball and rings. It quickly assumed its normal light, and after remaining thus for an hour and twenty minutes, it began to fade and so continued for an hour, having during that time entered and passed through the shade of the crape ring. It then entered the shadow of the bright rings, and rapidly disappeared.

From a great number of comparisons of the light of Japetus with two of the other satellites, a curve was drawn showing the light variations. This was published in the paper referred to.

This curve clearly showed what effect the crape ring had upon the light of the satellite. It showed that after passing through the sunlight shining between the ball and rings, Japetus entered the shadow of the crape ring. As it passed deeper into this, the absorption of sunlight became more and more pronounced, until finally the satellite entered the shadow of the bright ring. The crape ring was therefore transparent—the sunlight sifting through it. From the gradual absorption of light, it also showed that the crape ring was denser or less transparent as it neared the bright ring.

An inspection of the curve, and the observations, showed conclusively that there was no separating space, or division, between the inner bright ring and the crape ring as has frequently been represented in drawings. The transition from the one to the other, however, appears to be rather abrupt, as shown by the steepness of the curve at the time of contact with the shadow of the bright ring.

The observations also show that, so far as the penetration of the solar rays is concerned, the bright ring is fully as opaque as the globe of Saturn itself.

From the observations, I have deduced the following, Mt. Hamilton Mean Times.

		d	h	m
Japetus first seen (re-appearance from shadow of Ball)	1889 Nov.	1	14	37.4
Japetus last seen (contact with the shadow of Bright Ring)	1889 Nov.	1	17	11.0
An inspection of the light curve gives	1889 Nov.	1	15	47.2

as the most probable time of contact with the inner edge of the shadow of the crape ring.

For comparison, I append the predicted times of the above phenomena as given by Mr. Marth:

		d	h	m	
Re-appearance from Shadow of Ball	1889 Nov.	1	14	41	Bessel
" " " " "	1889 Nov.	1	14	59	Struve
Contact with Shadow of crape ring	1889 Nov.	1	15	41	
" " " " bright ring	1889 Nov.	1	17	17	

The observations are as accordant with theory as could be expected, since Mr. Marth states that 1″ in the heliocentric longitude of the satellite corresponded to an error of 36 minutes in the time. The two predictions for the re-appearance from the shadow of the ball, come respectively from using Bessel's and Struve's data for the diameter of the ball.

From the time required for the total emergence of Japetus from the shadow of the ball, and for its disappearance into the shadow of the bright ring, the satellite cannot be less than 1400 miles in diameter.

Unfortunately the contacts with the projection of the Cassini Division could not be observed here as the Sun rose before that phenomenon occurred.

From the light curve published in the number of the Monthly Notices referred to, I have obtained the following values which may be taken as fractions of a magnitude to represent the change in the light of Japetus due to the interposition of the crape ring between it and the Sun—or in other words, the absorptive power of the ring.

TABLE OF LIGHT VARIATION FROM THE LIGHT CURVE.

	h	m	m		h	m	m		h	m	m
Sidereal	6	10	0.780	Sidereal	7	0	0.520	Sidereal	7	47.5	0.050
		15	0.770			5	0.456			50†	− 0.030
		20	0.769			10	0.390			52.5	− 0.150
		25	0.765			15	0.348			53	− 0.260
		30	0.764			20	0.275			54	− 0.300
		35*	0.760			25	0.225			55	− 0.330
		40	0.748			30	0.168			57	− 0.400
		45	0.720			35	0.130			58	− 0.500
		50	0.678			40	0.098		7	59	− 0.600
	6	55	0.599		7	45	0.065				

* Enters shadow of Crape Ring. † Enters shadow of Bright Ring.

These figures between $6^h\ 35^m$ and $7^h\ 50^m$—during which time the satellite was passing through the shade of the crape ring—seem to indicate that the density of the crape ring increases proportionally to the distance from its inner edge, and the density at any point p will be

$$D = x$$

where x is the ratio of the distance of p from the inner edge in terms of the width of the crape ring, or, in the above table, an absorption of about 0.01 magnitude for each minute of time. If we assume a mean of the variations between $6^h\ 35^m$ and $7^h\ 45^m$, it will $= 0^m.412$ and will fall at $7^h\ 10^m$.

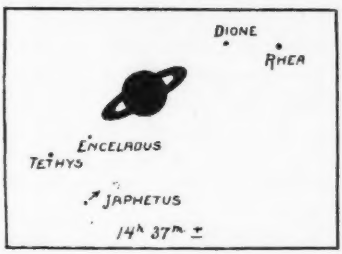
Applying this formula to the observations between the above times, the values contained in the following table under the head C will result—O being the values derived direct from the light curve:

TABLE REPRESENTING THE ABSORPTIVE POWER OF THE CRAPE RING.

	Time	O	C	o-c		Time	O	C	o-c
	h m					h m			
Sidereal	6 35	0.760	0.762	− 0.002	Sidereal	7 15	0.348	0.362	− 0.014
	40	0.748	0.712	+ 0.036		20	0.275	0.312	− 0.037
	45	0.720	0.662	+ 0.058		25	0.225	0.262	− 0.037
	50	0.678	0.612	+ 0.066		30	0.168	0.212	− 0.044
	6 55	0.599	0.562	+ 0.037		35	0.130	0.162	− 0.032
	7 0	0.520	0.512	+ 0.008		40	0.098	0.112	− 0.022
	5	0.456	0.462	− 0.006		7 45	0.065	0.062	+ 0.003
	7 10	0.390	0.412	− 0.022	Mean deviation				− 0.005

The entire absorptive power of the ring seems to be about 0.7 magnitude, which would, perhaps, be reduced somewhat if the light passed through the ring at a larger angle.

A formula which would more accurately represent the absorption could doubtless be found, but it is a question if it would have any truer signification than that given above.



The phenomenon of the eclipse can be accounted for on two suppositions. First, the crape ring is thinner toward the ball of Saturn; or second, there are fewer particles in that direction area for area. Perhaps both conditions prevail.

The increase of density towards the bright rings would rather favor the idea that the crape ring has its origin in the diffusion of particles from the bright ring.

I have assumed throughout these remarks, the theory that the rings are composed of individual particles.

As a matter of interest, I enclose a diagram of Saturn and five of the satellites at the epoch of the appearance of Japetus from the shadow of the ball. Enceladus and Tethys were the two satellites used for comparison of the light of Japetus during the eclipse. According to Professor Pickering, the difference in light between these two satellites is one magnitude.

In conclusion it is scarcely necessary to say that the observations of this eclipse settle forever the question of the transparency of the crape ring.

MT. HAMILTON, December 19, 1891.

ASTRO-PHYSICS.

FALL OF A SOLAR PROMINENCE INTO THE OPENING OF A SPOT.*

M. E. L. TROUVELOT, MEUDON OBSERVATORY, FRANCE.

On August 6, 1891, I was observing a large group of spots situated at some distance from the western limb of the Sun, toward which it was carried by the Sun's rotation. This group, which was composed of three spots in close proximity, exhibited some peculiarities which attracted my attention.

From the southern edge of the penumbra of the central spot of the group extended long and brilliant filaments which, at first separated, came closer together, as the distance increased, to form a bundle; this, crossing the umbra and penumbra of this spot as well as the southern penumbra of the third spot situated at the north of the group, passed on to sink and lose itself in the depths of its opening. The luminous filaments which crossed the central spot of the group were still sufficiently separated to allow the opening of the umbra of this spot to be recognized through the intervals between them; but beyond, the compact bundle allowed nothing more to be seen.

On August 8th the filamentous bridge uniting the two spots of the group was observed between passing clouds. On the 9th the group, very close to the Sun's limb, still showed the filamentous bridge, in spite of the unsteadiness of the image. Spectroscopic observation allowed the position of the central spot of the group to be determined, and it was found to be at 264° on the limb. Above this spot a few prominence jets were seen, in spite of the unfavorable state of the sky.

On August 10th, at $10^h\ 35^m$, the group of spots, which was then on the limb of the Sun, was no longer seen; but by the aid of the spectroscope it was easy to recognize the position of the spots. Brilliant eruptive jets shot out from a point situated at 264°, corresponding with the position of the umbra of the central spot of the group. All these incandescent jets were enclosed by an immense luminous arch, which, rising from a point situated at 258° on the limb, passed on to rejoin the chromosphere at another point situated at 270°, after having described a curve attaining an elevation of 2′ 40″ at its highest point.

This arch was composed of numerous filaments, formed of bril-

* "Comptes rendus de l'Académie des Sciences," 5 October, 1891.

liant knots joined end to end. The base of the arch at 258° was much broader, and composed of brighter and looser filaments than those which composed the other much narrower base. By its position, which corresponded exactly with that of the luminous bridge observed on the group of spots, by its greater width at the south than at the north, as well as by its form and filamentous structure, there can be no doubt that this prominence arch and the filamentous bundle observed on the spots were one and the same object, seen from different points of view.

These luminous filaments, rising to considerable elevations, uniting into a bundle, and passing on to precipitate themselves exactly into the distant opening of another spot, present a singular circumstance, which it would be difficult to attribute to chance.

My spectroscopic observations have taught me that, among the spots which cross the Sun's limb, there are some which are the seat of violent eruptions, and which throw jets of incandescent matter to great elevations, while there are others which exhibit no activity, and cross the limb without showing the smallest trace of an eruption. From the point of view of activity, Sun-spots may thus be divided into two classes: those which show traces of activity, and those which appear to lack them. It would seem that the study of spots from this point of view might lead to interesting results.

From the examination of the prominences observed August 10th above the group of spots in question, it seems evident that the filamentous arch owed its origin to the eruptive force escaping by the opening of the central spot of the group, situated just below this arch; a force which manifested itself by brilliant jets which rose from this opening. As not the least trace of eruption was noticed above the spot into which the narrow end of the arch descended, we may conclude that this spot was in a state of repose.

Must we attribute the fall of this prominence into the opening of the spot to the effect of chance, or to a kind of sucking phenomenon, or to some sort of attraction exerted on certain prominences by spots in a state of repose? Observations which I have often made on the Sun of phenomena of the same order, cause me to favor this last supposition.

REMARKS ON THE INFLUENCE OF THE ABERRATION OF LIGHT ON SPECTROSCOPIC OBSERVATIONS OF SOLAR PROMINENCES.*

M. FIZEAU.

Several recent communications have been presented to the Academy on the characteristic phenomena of the solar atmosphere, and especially on the circumstances of the appearance, development, and movement of the prominences, studied by means of spectrum analysis.

The authors of these communications, M. Trouvelot, M. Deslandres and M. Fényi, pursuing the path opened by M. Janssen, have observed and described several prominences remarkable for their brilliancy, their dimensions, and their changes in form; then, applying the principal of the displacement of lines by the movement of the luminous body, they have deduced the velocities of translation in the line of sight.

Without entering into the details of the observations with which we are dealing, the results as a whole tend to confirm the generally accepted opinion, that the prominences are due to vast gaseous eruptions, in which hydrogen predominates, and which rise rapidly, sometimes to enormous elevations above the solar surface, to return there at the end of a few hours; this seems to be the general conclusion from the quantities obtained in the measurement of the phenomena.

It seems then that, in these circumstances, great gaseous volumes are to be considered, animated with great movements, the velocities of which in various directions, are at once comparable with the velocity of light, the planetary movements, and, in particular, the movement of the Earth in its orbit.

One is thus led to investigate within what limits the well-known laws of aberration can here interpose, giving rise to those apparent displacements of stars, the images of which, either with the naked eye or telescope, almost always cause them to be seen displaced from their true position.

And, indeed, if one takes into account the reciprocal situations of the observer, placed on the earth, and the Sun, toward which the instruments are directed, it is evident that the simple and sensibly constant effect of aberration will be a diminution of 20″.445 in the longitude of the Sun and the prominences which rise from its surface, and that, moreover, this apparent displace-

* "Comptes rendus de l'Académie des Sciences," 7 Sept., 1891.

ment is due to the velocity of the earth in its orbit, which is 30.6 kilometres per second.

It results from these data that, if a prominence rises in the neighborhood of the ecliptic with a velocity of translation of the luminous gas equal to this same velocity of 30.6 kilometres per second, the position of the prominence will undergo a certain change, that is to say, an apparent displacement of $\pm 20''.445$, which will be added to or subtracted from the preceding effect according to the circumstances of direction, giving rise to corresponding variations in distance from the Sun's limb.

In truth, the velocities of the prominences are not uniform, and rarely attain the supposed value; but the nature of the phenomenon does not seem doubtful, and these great movements of the solar atmosphere, the existence of which is, however, not here contested, must give rise to apparent movements which depend upon the laws of aberration, and which must be taken account of in the more precise determination of the actual movements.

In what precedes, we have adopted the simplest hypothesis of the constitution of the prominences, that of the material transportation of hydrogen and metallic vapors rendered visible by their high temperature. An analogous reasoning applies, with still greater probability, to the hypothesis of the visibility of the prominences produced by an extraordinary development of electrical phenomena, similar to our storms and auroras.

That which gives to this point of view a special degree of probability, is the constant intervention of electricity in experiments where the hydrogen lines are observed.

Up to the present time, in spite of numerous attempts, hydrogen burning or heated, compressed or rarefied, does not seem to have shown its characteristic lines without the employment of electricity in the form of spark, current or discharge.

Now the prominences are always rose-colored, by the various lines of hydrogen, and particularly by the predominance of the red line C. Moreover the rapidity of changes in form, the sudden modifications in brightness, the longitudinally striped, undulated, broken appearance, with distorted parts completely isolated, and separated from the Sun's limb, have often been described. All these appearances agree without difficulty with the electrical hypothesis, and especially with the varied phenomena presented by the aurora borealis, in which there are striped appearances, fringed edges, luminous propagations sometimes slow, sometimes rapid, but generally with mean velocities, not as swift as light-

ning, nor as slow as the discharge of St. Elmo's fire or ball-lightning.

From this point of view, which seems to be at present adopted by many physicists and astronomers, the luminous appearances of the prominences must not be considered as due to movements of matter, but as resulting from the non-instantaneous propagation of electrical phenomena through the gaseous masses, which may have their own movements, but do not impose them on the electrical and luminous phenomena. These, completely independent of the first, can commence at the base, the middle, or the top of the prominence, and spread either up from below, or down from above, by successive movements which cannot fail to give rise, by the effect of aberration, to apparent displacements, similar to those mentioned above, but still more complex and more difficult to foresee.

It is proper to add here that, by the employment of wide slits, a general custom for exploring the forms and extent of prominences, the exact isolation of simple rays is given up, and one is liable to take for a displacement of lines by the motion, luminous manifestations of different intensity and appearance, which might be produced in different parts of a prominence.

Let us remark, in concluding, that if the intervention of the phenomena of aberration in certain studies of spectrum analysis is necessary for the exactness of measures, this intervention seems to be limited to a small number of phenomena, and notably that studies relative to the motions of the stars are not at all affected by it.

ON ABBERATION.*

M. MASCART.

In 1810 Arago† communicated to the first class of the Institute a memoir which was not published until some time after, on stellar refraction. In it the following remark occurs: " . . . The constant of aberration, which M. Delambre has found by the discussion of a large number of eclipses of satellites (Jupiter), is absolutely the same as that which Bradley has deduced from his observations.

"The first consequence that may be drawn from this remarkable agreement is that light travels uniformly, or at least

* From Comptes rendus, Nov. 2, 1891.

† Arago, Comptes rendus, V. XXXVI, p. 38, 1853.

without any ***sensible*** variation, in the whole space comprised by the orbit of the Earth; the eccentricity of the orbit of Jupiter allows this result to be extended so as to comprise the immense distance which it encloses. It is also natural to suppose that stars of different magnitudes are at different distances, and, as their absolute aberrations deduced from direct observations are sensibly the same, Bradley has concluded that the motion of light is uniform at all distances, and that the aberration of all celestial bodies can be calculated with the same constant."

After having given the details of his experiment, Arago ended by some conclusions, of which the first is:

"The aberrations of all the heavenly bodies, whether they send us their own or reflected light, can be calculated with the same constant, without the smallest difference in this respect, as I have deduced from my first experiments."

W. Struve, in a beautiful and important investigation on aberration, gives 20″.4451 for the constant, which is the mean of results differing but little among themselves, as determined from the observations of seven stars; but he adds "that it is necessary to assume for the seven stars the same constant of aberration, and consequently the same velocity of light."

The opinion of Bradley and O. Struve seems to have been unreservedly adopted by astronomers; it leads to the consequence that, if observation shows that aberration is exactly the same for all stars, the propagation of light must be uniform in all stellar space. This interpretation seems to me quite unwarranted by the results of observation.

The experiments made at the surface of the Earth by the method of Arago and that of our fellow member, M. Fizeau, determine the velocity of light in air, and consequently *in vacuo*, on the whole trajectory of the Earth. The eclipses of Jupiter's satellites, by deviations from the predicted times, give the time required for light to traverse the diameter of the Earth's orbit. The concordance of the result with that which can be deduced from the dimensions of the solar system, determined by other methods, also proves that the propagation of light is uniform in the interior of the terrestrial orbit. The eccentricity of the orbit of Jupiter perhaps allows this same result to be extended a little further, but not, as Arago has it, to the immense interval which this orbit encloses.

Aberration depends only on the ratio of the velocity of the observer to that of light in the region occupied by the instrument, and any modifications which may influence the propagation of

the light waves between the star and the Earth do not affect it. The constant of aberration may, however, change from one star to another, as Yvon Villarceau has shown, on account of the motion of the solar system. Variations in its amount will thus be of great interest.

Finally the displacement of the lines in stellar spectra gives only the relative velocity of the star and the Earth in the line which unites them.

If we reason rigorously, the deductions of direct experiments and astronomical observations which depend upon the velocity of light must thus be confined to the space comprised within the terrestrial orbit; only by induction can we go beyond it. It is hardly necessary to add that this induction seems legitimate; but, however probable it may be, it is a pure hypothesis to consider the progagation of light as uniform in celestial space.

THE LARGE SUN-SPOT GROUP OF AUG. 28--OCT. 4, 1891.*

REV. A. L. CORTIE.

The following notes on some telescopic and spectroscopic phenomena observed in this large group of spots are intended to supplement the note by Father Sidgreaves in the October number of the *Observatory*.† The group was born on Aug. 28 at the eastern limb, its mean heliographic co-ordinates being lat. 18°.5 N. and long. 221°.0. It died on Oct. 4, on the western limb, in lat. 22°.0 N. and long. 226°.7. It thus both formed and died on the visible hemisphere. Moreover it was the largest group of spots observed since June, 1885, and one of the largest since the great November spot of 1882. Fourteen drawings were obtained of the group at Stonyhurst. During its first passage over the disk, Aug. 28–Sept. 10, it consisted mainly of two very large irregular spots. The following of these was by far the largest spot of the group, and underwent the greatest internal changes. It did not, however, survive to a second rotation; for then the preceding spot alone appeared, being accompanied in its passage across the disk by occasional outbreaks of small spots scattered over a wide area.

At its birth the group was surrounded by bright compact faculæ, one scimitar-shaped jet lying S. of the preceding spot being

* From The *Observatory*, November, 1891.

† See also ASTRONOMY AND ASTRO-PHYSICS, January, 1892, p. 66.

especially remarkable. At its death the faculæ were still very bright, but were vastly more extensive.

The area of the group at its birth on Aug. 28 was 77 millionths of the visible hemisphere. As it crossed the disk it steadily developed, and attained its greatest area of 1834 millionths on Sept. 7. At its reappearance after one rotation on Sept. 25, the area had diminished to 545 millionths. The diminution continued until the extinction of the spot on Oct. 4.

The group displayed some remarkable proper motions, the two members repelling one another, except for a slight approach on Sept. 3. At their birth on Aug. 28 the two spots were 3°.6 apart in longitude, which was increased to 5°.9 on Aug. 29; to 10°.4 on Sept. 2; to 11°.8 on Sept 4; and to 13°.0 on Sept. 7. Between Sept. 7th and the 9th, the following spot changed its retrograde motion to one of approach, but its companion gave at the same time such a leap forward, that on the 9th their distance apart reached its maximum of 16°.5. This forward motion of the whole group took place just after it had attained its greatest area.

Fig. 1.

F  P

Spot B. Spot A.

Considering the motions of the individual spots, that of the preceding member of the group was very rapid, as it advanced from long. 222°.8 to 233°.8 between Aug. 28th and Sept. 9, or 11° in 12 days. Its most rapid drift of 4°.7 in two days took place between Sept. 7th and 9th. The drift of the following spot in the contrary direction was not at all great; but 3°.1 in the 10 days, Aug. 28–Sept. 7, and from long. 219°.2 to 216°.1. Both the spots rose in latitude, the mean drift of the group being from 18°.5 N. to 22°.2, while the individual drifts were from 19° to 21°.8 and from 18°.0 to 22°.5 for the preceding and following spots respectively. Their common advance in longitude Sept. 7–9 was accompanied by a slight fall in latitude, so that their paths were almost parallel. The end of the first rotation was marked by the metallic prominence of Sept. 10 immediately over the following spot, which was then exactly on the limb.

At the beginning of the second rotation the preceding spot, which now alone remained, was found on Sept. 25 in lat. 23° and long. 228°.3. Excluding possible oscillations, it had therefore, when on the invisible hemisphere, drifted 1°.8 higher in latitude, but retrograded 5°.5 in longitude. Until Sept. 28 it remained almost stationary, but from the 28th to the 29th it suddenly rose

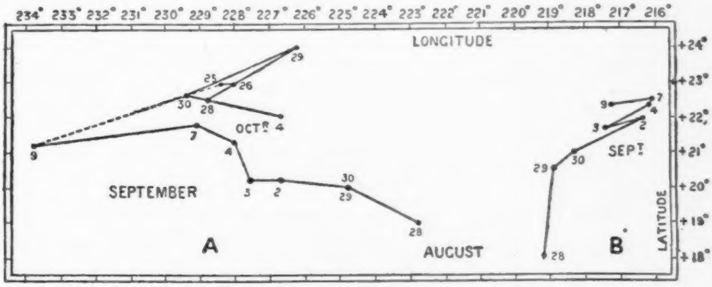
1°.5 in latitude and advanced 2°.6 in longitude. Next day it as suddenly dropped to almost exactly its original position in latitude, and retrograded 3°.1 in longitude. This seems to have been its expiring effort, as on Oct. 4 it was represented by a group of minute scattered dots. Therefore while the following and larger spot remained comparatively stationary, the preceding spot drifted rapidly forward in longitude in the first rotation, and retrograded in the second rotation, so that when it died it was but 3°.9 in advance of its first position.

In the spectroscope the most important spot of the group was the one marked B in the figure. The following are some of the details of the variations in the hydrogen C line over the spots when they were on the visible disk. The observations were taken during a vacation visit to the Stonyhurst Observatory, at the kind invitation of the Director. On Aug. 30, at 11 A. M. G. M. T., in a hazy sky, and employing a dispersion of 6 prisms of 60°, the line was seen to be reversed and displaced towards the violet in the preceding portion of the nucleus of the following spot. There was also a less brilliant reversal of the line noted in the faculæ which was situated between the two spots, while in that which followed the group the line was broken though unreversed.

The next observation was on Sept. 3d in excellent definition, so that the full battery of 12 prisms of 60° and a high magnifying-power were employed. The following of the two spots was seen to be broken up into a number of separate nuclei, with penumbral and faculous matter filling up the spaces between. As on Aug. 30, so now too, the C line was unaffected by the preceding spot. But in its companion some remarkable reversals and displace ments of the line were observed. By carefully bringing the slit over various portions of the spot, it was possible to locate the chief seat of disturbance as being situated in the northern half of the spot, and in the faculous and penumbral gap which intervened between this and the southern half. At 11:30 the line was broken in the penumbral gap, and a small portion was twisted and blown towards the violet. It was pear-shaped, with the stem adhering to the dark line. It gave the impression of fluttering about, as if blown by a wind. The estimated displacement was 0.7 X-metre, and the appearance lasted for about three minutes. It was not seen again, but subsequently the line became very much widened on both sides. At 11:53 the line was reversed in that nucleus which was situated in the N.F part of the spot. At 12:15 it became less dark in this same nucleus, and in the penumbral gap had a thin hair adhering to it and turned towards the

red. The motion therefore of the dark hydrogen had been reversed from an uprush to a downrush. The thin hair-like line formed an angle of about 30° with the main line. Lower down this latter was reversed as a bright dot probably in a region of faculæ, and below this again was greatly thickened in some penumbræ. Hence five different appearances of the line were to be seen in the same field. At 12:35 the thin line had vanished, a thickening of the main line having taken its place. When the group was sketched next morning at 9:45, it was seen that the aspect of the spot had changed in that very portion in which the disturbance had been observed in the spectroscope. On Sept. 6th, at 3 P. M., the C line over this same spot was less dark but otherwise unaffected.

Fig. 2.



On Sept. 28th, at 12 P. M., the C line was reversed in the nucleus of the preceding spot, which now alone survived. It is noteworthy that as in the case of its companion, so now too, a reversal of the hydrogen line heralded its speedy dissolution. Nor must we omit to call attention to the fact that the independent observations of the reversals and twistings of the C line on Aug. 30 and Sept. 3, and the observation of the metallic prominence on Sept. 10, agree in placing the seat of greatest activity as occurring in the same portion of the following spot of the group. As the scope of the details just described is only to supplement the observation of the metallic prominence, all reference to the observations of the remaining lines between B–D in the spectrum of the group has been omitted, as they will, it is hoped, be more appropriately published elsewhere.

ST. BEUNO'S COLLEGE, St. Asaph, 1891, Oct. 17.

ON THE DISTRIBUTION IN LATITUDE OF THE SOLAR PHENOMENA OBSERVED AT THE ROYAL OBSERVATORY OF THE ROMAN COLLEGE, DURING THE FIRST HALF OF 1891.*

M. P. TACCHINI.

Below are the results which relate to each zone of 10° in the two hemispheres of the Sun:

PROMINENCES.

1891.	First Qr.	Second Qr.
90° + 80°...	0.003	0.003
80 + 70 ...	0.000	0.006
70 + 60 ...	0.006	0.003
60 + 50 ...	0.053	0.052
50 + 40 ...	0.115	0.134
40 + 30 ...	0.073	0.105
30 + 20 ...	0.115	0.087
20 + 10 ...	0.050	0.073
10 . 0 ...	0.038	0.023
	0.453	0.486
0° − 10°...	0.018	0.017
10 − 20 ...	0.050	0.052
20 − 30 ...	0.112	0.087
30 − 40 ...	0.079	0.122
40 − 50 ...	0.206	0.078
50 − 60 ...	0.067	0.125
60 − 70 ...	0.003	0.015
70 − 80 ...	0.009	0.009
80 − 90 ...	0.003	0.009
	0.547	0.514

FACULÆ.

1891.	First Qr.	Second Qr.
40° + 30° ...	0.027	0.057
30 + 20 ...	0.280	0.335
20 + 10 ...	0.200	0.272
10 . 0 ...	0.040	0.006
	0.547	0.670
0° − 10°...	0.053	0.019
10 − 20 ...	0.200	0.127
20 − 30 ...	0.187	0.133
30 − 40 ...	0.013	0.051
	0.453	0.330

SPOTS.

1891.	First Qr.	Second Qr.
40° + 30°...	0.000	0.000
30 + 20 ...	0.214	0.304
20 + 10 ...	0.357	0.321
10 . 0 ...	0.036	0.054
	0.607	0.679

SPOTS.

1891.	First Qr.	Second Qr.
0° − 10°...	0.000	0.015
10 − 20 ...	0.036	0.100
20 − 30 ...	0.250	0.128
30 − 40 ...	0.107	0.078
	0.393	0.321

ERUPTIONS.

1891.	First Qr.	Second Qr.
50° + 40°...	0.000	0.000
40 + 30 ...	0.000	0.000
30 + 20 ...	0.200	0.000
20 + 10 ...	0.200	0.500
10 . 0 ...	0.000	0.000
	0.400	0.500
0° − 10°...	0.000	0.000
10 − 20 ...	0.200	0.500
20 − 30 ...	0.200	0.000
30 − 40 ...	0.000	0.000
40 − 50 ...	0.200	0.000
	0.600	0.500

It may be seen that, during the first half of 1891, the solar prominences have been more frequent in the southern hemisphere, as in 1889 and 1890, with the maximum of frequency always in the zones (± 40° ± 50°), while the spots have maintained their great predominance to the north of the equator, like the faculæ, with maxima at lower latitudes, as compared with the prominences. All the phenomena are very infrequent in the neighborhood of the solar equator.

Resume of Solar Observations made at the Royal Observatory of the Roman College during the Third Quarter of 1891.†

The number of observing days was 31 in July, 31 in August, and 19 in September. The following results were obtained:

* "Comptes rendus de l'Academie des Sciences," 7 Sept., 1891.
† From "Comptes rendus," Nov. 30, 1891.

1891.	Relative Frequency Of Spots.	Of Days without spots.	Relative Size. Of Spots.	Of Faculæ.	No. Groups Per day.
July	18.65	0.00	76.26	82.03	4.03
August	8.84	0.06	49.06	70.81	2.94
September	17.52	0.00	114.45	61.10	4.10

By comparing these data with the results of the observations made during the preceding quarter, it will be seen that the solar activity has considerably increased, for the extent of the spots is twice as great. It is also shown that the minimum of faculæ corresponds to the maximum spot extent.

The season has been equally favorable for prominences. The following results have been obtained:

1891.	Number of observing days.	Prominences. Mean number.	Mean height.	Mean extent.
July	30	8.37	40.2″	1.4
August	30	6.77	41.0	1.9
September	23	9.26	41.4	2.2

As in the case of spots, we have thus established a sensible increase in prominence phenomena. The greatest height observed for a prominence was 142″, in the month of August; there have been but few metallic eruptions, although interesting peculiarities were observed in several prominences, especially during the month of August.

THE CHROMOSPHERE LINE ANGSTRÖM 6676.9.

A. L. CORTIE.

With regard to Professor Young's observations as to the non-coincidence of the bright chromosphere line* (*Nature*, November 12, p. 28) with the corresponding dark line 6676.9 of Angström's scale, it may be interesting to note that Professors Liveing and Dewar have observed a barium line at 6677, which is therefore slightly less refrangible than the dark solar line. In his catalogue Professor Young also gives a barium line at 6018.0, which is identified with Kirchoff 933.8. In the course of the observations of Sun-spot spectra taken at Stonyhurst with a twelve-prism spectroscope, no dark solar line has been noted in this position except in two uncertain instances over spots. It would be an important fact should two barium lines be found in the chromosphere without corresponding dark lines.

* See also Astronomy and Astro-Physics, January 1892, p. 59.

In the period of maximum solar activity the bright line 6676.9 was on several occasions seen in the spectroscope, while the height of the chromosphere was being measured at Stonyhurst on the C line of hydrogen. At these times C was always very bright, and generally displaced in the prominences in which 6676.9 was seen. The latter line was not seen in the observations taken between March 9, 1886, and September 10, 1891. Although both Young and Thollon attribute the line to iron, no iron line is given in this position by either Angström or the catalogues of the British Association. Dunér, quoted by Thollon, considers the line variable with the state of solar activity, but Angström seems to have made an error in drawing it as a fine thin line, as Kirchoff, Burton, Fievez, Smyth, Thollon and Higgs give it as a strong dark line. Finally, Young, Burton, and the Stonyhurst observers identify it with Kirchoff's ray 654.3, and Thollon with 641, which latter is a calcium line. There would, then, appear to be some differences of opinion with regard to this important line (cf. *Monthly Notices R. A. S.*, Vol. li., No. 1, p. 22.)

St. Beuno's College, St. Asaph, November 19.

NOTES ON THE USE OF THE SPECTROSCOPE FOR SKETCHING SOLAR PROMINENCES, AND FOR OBSERVING THE SPECTRA OF THE SPOTS AND PROMINENCES.*

WALTER SIDGREAVES.

In the June number of the *Journal* a general division of the work on the Sun that might be undertaken with the spectroscope was given under five headings. The Director of the section hoped to accomplish during the summer vacation more than the cloudy condition of the atmosphere has allowed him to realize. Nevertheless a series of experiments with a student's spectroscope of a single 60° prism of dense glass by Hilger, may serve their purpose sufficiently, which is, not to guide those who are already well equipped for the work, but to help others of our associates who may be willing to join the section as soon as they see that they can contribute to its success by collecting material for the study of solar physics.

The spectroscope was fitted to the eye end of a telescope, which is easily mounted on a strong iron pedestal in the college garden near the Observatory. The object glass, by Alvan Clark, is of

* *Jour. British Astr. Assoc.*, Oct., 1891.

$5\frac{1}{2}$ inches aperture. A much smaller objective would do equally well, if mounted on a tube and axle strong enough to carry the spectroscope and requisite counterpoises. The instrument is fitted with the ordinary equatorial gear, but has no clockwork, and depends upon its slow motion rod for retaining the image. So that the results obtained will show what may be done with the least of needful appliances.

The prominences were easily seen, and their heights could have been measured with the aid of a divided scale in the eye-piece. The spectrum of a spot showed very well, and its lines could be examined while the spot travelled across the field along the slit. The addition of clock movement to the instrument would have rendered the observing quite easy.

For work upon the prominences a position circle would be needed in addition to the divided glass scale, in order to measure the base as well as the height of each, and to tabulate their heliographic latitudes.

A remark here may be of service to observers of the solar prominences. Within the limits of dispersion sufficient to show the bright lines of the chromosphere smaller dispersion should give a more accurate measure of the height of a prominence than greater dispersion. For the line is brighter with the smaller dispersion, and is, therefore, not only visible to a greater height where intensity fades, but will bear a greater magnification. And the ocular magnification is the only help to the measurement, dispersion adds nothing to the apparent length of the line.

For observations of the spectra of the spots and prominences, a good map of the solar absorption spectrum, suited to the degree of dispersion employed, is almost indispensable. At the end of the second volume of the "Publicationen des Astrophysikalischen Observatoriums zu Potsdam" (Engelmann-Leipzic 1881), two excellent maps are given for moderate and for small dispersions. With the help of these and of their accompanying wave-length catalogues, the observer can readily identify any lines that are affected by a spot or by a prominence. He would, however, probably find but little work of this kind on the prominences, which, so far as we know at present, only rarely show other bright lines than D_3 and the Hydrogen reversals. The tips of the absorption lines as seen with the slit lying radially over the Sun's limb should be carefully scrutinised, with a very well adjusted instrument, for a small reversal, as the bright line may reach up to only a small fraction of the normal height of the chromosphere.

The spectra of the spots afford more work for the observer. When the image of a spot is on the slit, its spectrum appears as a thick, or fine dust line according to the size of the spot, but readily distinguishable from these flaws by its flocculent appearance, and is infallibly recognized by its movement with the clock variations when the slit is set parallel to the equator.

The following observations seem to be well within the means of a small dispersing spectroscope:—

1. To note, according to some scale of difference, the general density or darkness of the band, and whether the density appears to be maintained throughout the length of the spectrum, or to be greater in some parts than in others.
2. To note whether the solar lines appear to be of uniform thickness where they cross the spot, or to taper like a spindle towards the penumbral regions.
3. To look for thickening of any lines as they cross the spot band, notably the prominent lines C, D_1, D_2, E, &c., expressing the widening in the degrees of comparison, "widened," "more widened," and "most widened" where *more widened* would mean between one-half and the whole width of the line as seen on the Sun off the spot.
4. To note any alteration of intensity of the line over a spot, whether entirely obliterated, or even reversed.
5. To note any distortion of a line, and to which end of the spectrum the bend lies.

In all these observations an accurate adjustment of the instrument is of the greatest importance. To detect a very short reversal of a line in the chromosphere, the Sun's limb must be very sharply defined, together with the perfect definition of the absorption lines. When this is obtained, the spectrum of a spot will also show a well-cut band with clearly marked shadings responding to every degree of density in the nucleus and penumbra. The following method of finding the true adjustment is both convenient and speedy. The solar image is first brought to an approximate focus on the slit. Then the eye-piece is adjusted to give sharply defined edges to the color band. Thirdly, the absorption lines are brought to focus with the collimator. This last movement spoils the definition of the edges; but by moving both the collimator and the eye-piece simultaneously or alternately, the lines are quickly brought to focus coincidently with a sharp definition of the edges of the band. Lastly, the slit is set radially over the Sun's image, with the limb cutting it in the middle, and the tele-

scope rack is moved until the edge of the color band given by the Sun's limb appears as a sharply cut line. This last movement gives the true position of the solar image, which is not precisely that of its best definition on the slit plates.

The chromosphere and prominences are always measured here with the slit radially over the Sun's limb by a finely divided scale on clean glass cemented to the cross-line-plate of the eye-piece. The spectroscope is mounted eccentrically on the position circle at such distance from the center that only a very small band of the solar spectrum is visible in the field. And the band is reduced to nothing when the details of a prominence are to be examined with an open slit. This adjustment of the open slit is quite as effective as the tangential position, and is better suited to our method of measuring the heights of the chromosphere and prominences.

The spot spectra are always observed with the slit set parallel to the equator in order that any variation of the clock movement may not throw the spot off the slit. The true orientation of the slit is found by turning the position circle or holder until the chromosphere remains visible in the line C, while the image of the Sun's northern or southern limb travels the length of the slit.

With a telescope of long focal length the Sun's image is large enough to show a spot on the slit plates, and then it can be easily brought on to the slit by the slow moving gear. With smaller telescopes the plan is to sweep the slit across the solar image by means of the N. P. D. rod until a spot band flashes along the spectrum. But if a grating or a single prism be employed for the spectrum, the method suggested by Mr. Townsend, of Stamford Lodge, Sevenoaks, is clearly the simplest and the most efficient process. He turns his grating to serve as a white light reflector, and opens the slit as wide as possible, so as to view the Sun's disk through the eye-piece of the spectroscope protected with a dark glass. The spot selected for observation is then retained between the jaws of the slit by the AR rod while the slit is closed to the required fineness. One of the faces of the single prism can be employed as a first surface reflector in the same manner. This method is so convenient and efficient, both for finding a spot and for the orientation of the slit, that where a train of prisms is employed, a separate reflector for the purpose would be a valuable addition to the instrument, whether as a solar or as a stellar spectroscope.

STONYHURST OBSERVATORY, Lancashire.

THE MODERN SPECTROSCOPE.

II.

*The Star Spectroscope of the Lick Observatory.**

JAMES E. KEELER.

In designing a spectroscope for so large a telescope as the thirty-six-inch refractor of the Lick Observatory, the weight of the instrument is not a consideration of special importance. Adding another hundred pounds, more or less, to a telescope already weighing several thousand, has no prejudicial effect upon the stability of the mounting or the performance of the driving clock, and the size of the spectroscope is practically determined by the opitical power desired or by considerations of convenience in handling. In the case of the thirty-six-inch refractor, the weight of the parts requisite to give sufficient rigidity is considerably increased by the unusually great ratio of focal length to aperture, as the length of the collimator must be nineteen times the desired effective aperture of the spectroscope, and hence the most important parts must be supported at a considerable distance outside the focal plane of the telescope.

The weight of the Lick Observatory spectroscope is nearly 130 pounds; with the two brass rods forming the connection with the telescope it is perhaps 75 or 80 pounds more.

A perspective view of the instrument, (from a photograph by Mr. Barnard) is given on Plate V, and a scale drawing, with reference letters, on Plate VI. In the latter figure the observing telescope is shown with its axis parallel to that of the collimator.

The lower part of the eye-end of the great telescope is surrounded by a revolving jacket, which is furnished with slow motion screws, clamp, and position circle. On each side are cast three strong clamps, bored slightly larger than the brass rods, *A*, *B*, which support the spectroscope. The rods (or rather tubes, for although closed at the ends, they are hollow), are 3 inches in diameter and 6 feet long. They are inserted for 2½ feet of their length in the clamps on the revolving jacket, and project 2 feet 3 inches beyond the focal plane of the telescope. The distance between their centers is 23¼ inches. On the upper end of each rod is a short circular nut, and near the lower end is a projecting pin, which serves to always bring the spectroscope into the same position with respect to the telescope. When all the clamps are

* Communicated by the author.

tightened, the rods form a very rigid support for the spectroscope.

The brass frame, *C*, of the spectroscope is cast in a single piece. It is secured to the rods by four clamps, the arrangement of which is shown in the figure. The lower half of each clamp is a single piece; the upper half is made with a tight-fitting hinge, so that it can be turned back on the frame. The clamps have a small amount of lateral motion, so that they can adjust themselves to the distance between the rods, and one of them can be rotated on an axis perpendicular to the plane of the rods, an arangement which prevents the spectroscope frame from being strained on tightening the clamps. The clamps were properly adjusted on first mounting the spectroscope, and since then no change has been necessary.

In mounting the spectroscope, the eye-end of the great telescope tube is first supported by a prop. The rods are then inserted and fixed. The spectroscope is placed upon the rods and allowed to slide down until it rests upon the stops provided for the purpose on their lower ends, and all the clamps are tightened. Balancing weights equivalent to the weight of the spectroscope are then removed from the lower part of the telescope tube, completing the operation, which requires the work of two persons for about twenty minutes.

The collimator, *G*, slides in the case, *D*, which is connected with the frame by opposing screws, so that the collimator axis can be directed to the center of the great objective. The collimator can be moved through a range of about 100 millimeters by turning a large milled head, *z*, its position being indicated by an index moving along a millimeter scale. The collimator objective has a focal length of 20 inches and an aperture of 1½ inches. It is made of Jena glass, and the lenses are cemented together with Canada balsam to diminish the loss of light by reflection.

The slit, *s*, is provided with a rack and pinion for focusing, and a clamp. Its jaws move equally in opposite directions from the center by turning a right and left-handed screw. By turning a small pinion, not shown in the figure, the length of the slit can also be varied. *q* is a diagonal eye-piece which moves between stops, so that when pushed in the slit can be viewed from behind, and when withdrawn the rays from the slit pass without obstruction. This eye-piece is essential in so large an instrument, for ensuring that the image of the celestial object under examination is properly adjusted on the slit plate. *r* is a pinion head

for moving the 60° totally-reflecting prism along the slit plate. When moved fully in toward the center, the reflecting angle of the prism extends a little beyond the center of the slit.

The slit and its accessories are protected from accidental disturbance by a thin tube, *H*, which also serves to hold the tube, *t*, for cylindrical lenses.

The strong cross-piece which carries the observing telescope has two pivots, one on each side of the spectroscope frame. At *F* is the graduated circle, 12 inches in diameter, divided on the edge, on silver, to 10′ and read by two opposite verniers to 10″. The circle is held by the clamping nut, *p*, and when the latter is loosened, it can be turned so as to bring any desired graduation to the index of the vernier when the observing telescope is directed to the slit. In general the reading of the circle for this position of the observing telescope is made 0°, and the reading for any other position gives directly the deviation of the ray observed; *h* is the clamp and tangent screw for slow motion of the observing telescope, and *o* is a reading lens and shade. The vernier at *o* is illuminated by the electric lantern, *i*.

The smaller head shown at *p* secures the outer end of the long spindle which forms one of the bearings of the observing telescope.

Two observing telescopes are provided. The one shown in the figure has a Jena glass objective of 1½ inches aperture and 10 inches focal length. The other, which is twice as long, is used with a grating for solar spectroscopy. The micrometer, and other accessories, are made to fit both of these telescopes. The short telescope, *E*, is more convenient when prisms are employed, or for observation of faint objects with low magnifying powers.

The micrometer, *m*, carries a fine wire, a coarse wire, and a pointer. The head is divided into 100 parts, and one revolution (when the small telescope is used) is equal to 3′ 10″.8. A quicker motion would be preferable. The number of whole revolutions is indicated on a dial.

A small incandescent electric lamp in the lantern, *i*, illuminates both the upper vernier of the graduated circle and the wires of the micrometer. It is connected by flexible wire with the binding posts, *f*. The color of the light which enters the micrometer box can be varied, so as to approximately match that of any part of the spectrum, by means of a revolving disc, *i*, containing colored glass, and its intensity is regulated by turning the short tube, *k*, which contains a small reflecting prism.

The two eye-pieces which are generally used on the short telescope are achromatic and they have magnifying powers of 7.3 and 13.3 diameters. An eyepiece giving a power of 7 on the long telescope is also provided.

The observing telescope is counterpoised by the weight, *I*. Additional counterpoises are supplied for the long telescope and the reversion apparatus.

Three prisms are used with the spectroscope, two of them being single prisms of 30° and 60° refracting angles respectively, and the third a compound prism of high dispersion. Each prism is cemented to a separate table, or circular plate of brass, which stands upon three short foot-screws. Two long clamping screws hold this plate firmly against the grating table, *a*. The prisms are therefore readily interchangeable, and require no attention after a final adjustment of the foot screws has been made. Each prism is provided with a light cover, *b*, which is blackened inside and out to prevent reflections.

The grating table *a*, is attached to the end of a long conical spindle, which passes through the hollow pivot of the observing telescope arm, and carries at the other extremity *D*, a disc, *c*, with ratching on its circumference. By means of a tangent screw, *d*, a slow rotary motion can be given to the grating table. *e* is a small lever by which the tangent screw can be thrown out of gear, and the grating table can then be rotated freely by hand.

Just below the grating table, the spindle is encircled by a collar, to which is attached the tail-piece of the minimum deviation apparatus, *g*, and the collar is clamped to the spindle of the grating table by a screw *h*. By the construction of the apparatus the tail-piece is made to always bisect the angle between the axes of the collimator and the observing telescope. When a prism is to be used it is first set to the position of minimum deviation for any line of the spectrum, by means of the tangent screw, *d*; the clamp, *h*, is then tightened, and the tangent screw is thrown out of gear. The prism will then be automatically kept in the position of minimum deviation for all parts of the spectrum.

When the grating is used, the minimum deviation apparatus is unclamped, and the grating is held in position by the tangent screw. It is then, of course, entirely independent of the observing telescope. The Rowland grating has 14438 lines to the inch, and gives very brilliant spectra of the higher orders on one side. The mounting by which it is held to the grating table does not differ from the form in common use.

At *K* is shown the apparatus for producing comparison spectra. But little explanation is required. *w* are the forceps for holding metallic electrodes. *w* is a rack-and-pinion for moving the spark in the line of the forceps. A motion at right angles to this direction is obtained by rotating the forceps-holder in its collar. *v* is a short tube holding a lens, by which an image of the spark is formed on the slit, and as the angular aperture of this lens is greater than that of the collimator objective, the entire collimator aperture is filled with light from the spark. *y* is a tube in which *v* slides. A neutral-tint compensated wedge can be inserted in the rectangular aperture shown in *y*, if it is necessary to reduce the light. The forceps-holder can be removed, and replaced by a somewhat similar arrangement, having no rack-and-pinion motion, for holding spectrum tubes.

A box (not shown in the figure) containing an elaborate reversion attachment, can be inserted between the observing telescope and its supporting arm. The single reversion prism, which is of the form described by Dr. Carl Braun in the publications of the Haynald Observatory, is rotated by a very fine micrometer screw, acting on the end of a long arm. The apparatus is somewhat similar in principle to the prismatic sextant of Pistor and Martins, the micrometer screw replacing the graduated arc of the latter instrument, but the reversion prism allows an object in the line of sight to be seen after but one reflection. The reflecting face of the reversion prism is slightly inclined to the refracting edge, so that the direct and reflected spectra do not coincide, but are in close juxtaposition. The relative brightness of the two images can be varied. This apparatus answers well for bright objects.

The Lick Observatory spectroscope has an effective aperture of 1.06 inches, when used in connection with the 36-inch refractor. When it is not in use on the telescope it rests upon a truck, and the full aperture of the spectroscope, 1.50 inches, becomes available for laboratory work. The truck is fitted with drawers for holding accessories. There are no photographic attachments.

All parts of the instrument (except one of the prisms) were made by Mr. J. A. Brashear, of Allegheny, Pa., and the workmanship is of the highest class. The design has also proved to be satisfactory for all purposes of eye observation.

PLATE V.

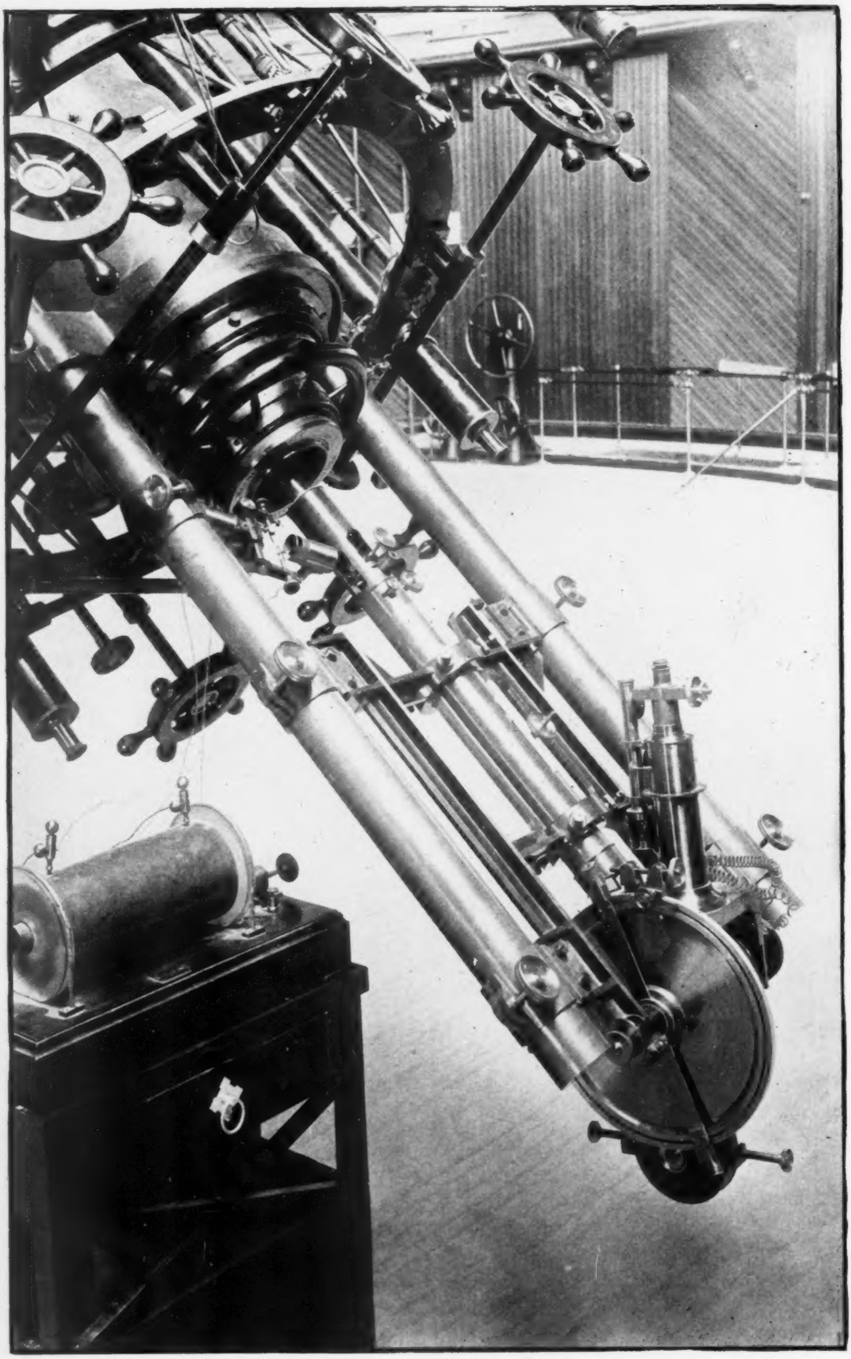


Plate accompanying Professor Keeler's paper on the Star Spectroscope of the Lick Observatory.

PLATE VI.

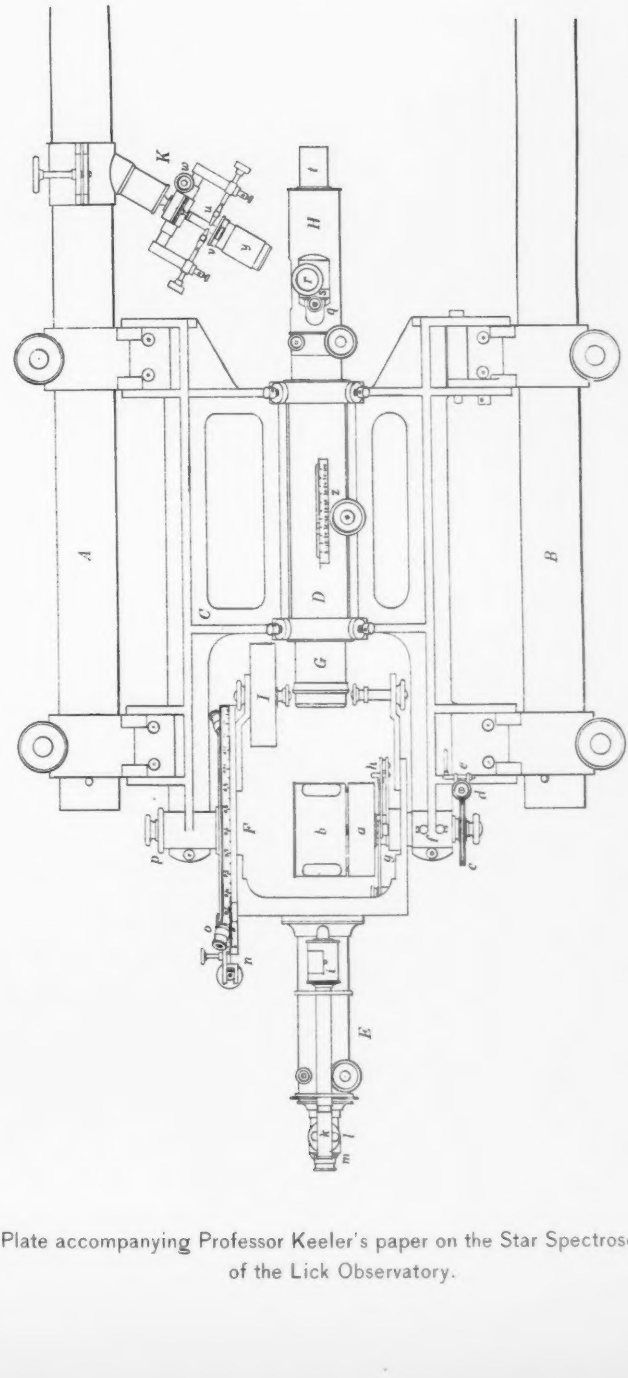


Plate accompanying Professor Keeler's paper on the Star Spectroscope of the Lick Observatory.

STARS OF THE FIRST AND SECOND TYPES OF SPECTRUM.*

E. W. MAUNDER, F. R. A. S.

The question of stellar evolution has been much discussed during the past few years, and not a few new facts bearing upon it have been recently brought forward, and the consideration of some of these has led me to think that some conclusions which have been very generally accepted require not a little modification.

It is, of course, well-known to all that stellar spectra are by no means of one uniform appearance, and that they show strongly marked and striking differences, four leading types being readily recognized. These types, if we follow Secchi's numeration, may be briefly described as follows:—

TYPE I.—Color of the stars, usually white or bluish. *Examples:* Sirius, Vega, Altair. Characteristics: the hydrogen lines are very strongly marked, being broad, dark, and diffused at the edges, but the lines of the metals are inconspicuous.

TYPE II.—Color of the stars, mostly yellow. *Examples:* the Sun, Arcturus, Capella, Aldebaran. Characteristics: the hydrogen lines are present, but are not specially pronounced; whilst the metallic lines are numerous and distinct.

TYPE III.—Color of the stars, mostly orange. *Examples:* Betelgeuse, Antares, α Herculis. Characteristic: a number of shaded bands are seen, which are each darkest at the end nearest the violet, and shade off towards the red.

TYPE IV.—Color mostly red. *Examples:* 19 Piscium, 152 Schjellerup, no very bright stars. Characteristic: the presence of shaded bands due to carbon, which shade off in the opposite direction to those of the preceding type.

It was very natural that so soon as this classification was recognized, these several types should be interpreted as representing different successive epochs in the life history of a star. Generally speaking, it has been supposed that the Sirian or first type indicates the earliest period, that of highest temperature, that as a star cools, it enters on the Solar or second stage, and with yet a further cooling, on a stage represented by one of the two orders of shaded spectra. With this idea, it has been very customary to speak of the Sirian stars as being on the average much larger than stars resembling our Sun in spectrum. Thus the late R. A. Proctor, writing in reference to them, says, "the stars belonging to this type are certainly in many cases, and probably in all,

* *Jour. British Astr. Assoc.*, Oct., 1891.

very large orbs," and he often spoke of them as "giant suns," a practice in which many other writers have imitated him.

This was a very natural inference, for on the assumption referred to above, that a first type spectrum indicates that the star possessing it is in the earliest stage, that of highest temperature, we should infer: (1.) That Sirian stars had on the average a greater mass than Solar stars, for the larger the star, the slower would be the process of cooling. (2.) Sirian stars would on the average be less condensed than Solar stars, and having a larger mass, must needs have a much larger volume. (3.) Having a much larger surface than Solar stars, and being at a higher temperature, they should emit, on the average, a very much greater amount of light.

It must be borne in mind that these differences cannot, on the assumption referred to, be slight or insignificant in the mean. Since the whole history of stellar evolution is summed up in but three or four stages, each stage must represent enormous periods of time, and the difference between a star in the height of the first period, and the same star in the height of the second, must be very great indeed, both as to the degree of condensation, temperature and total radiation. If there are the materials for instituting a comparison between the actual brightness of stars of the different types, the first type should come out as the most luminous, beyond all possibility of doubt.

The materials for such a comparison within our reach are very slight, but such as they are, they do not point to any such predominence in brightness (total radiating power) of the Sirian stars. First we have a few stars of which the parallaxes are known, and, knowing their distances and their apparent magnitudes, we can compute the absolute light-giving power of each. The result of the comparison is given below, the Sun being taken as unity. The magnitudes have been taken from the Oxford Uranometria, the Sun being assumed to be 26½ magnitudes brighter than an average first magnitude star.

SIRIAN STARS.

β Cassiopieæ	12.3	Procyon	23.7	α Draconis	1.7
α Persei	83.0	Regulus	108.0	α Aquilæ	25.8
Sirius	42.4	α Lyræ	2048.1	α Cephei	67.8

SOLAR STARS.

α Cassiopeiæ	59.7	Aldebaran	71.3	π Herculis	28.0
η Cassiopeiæ	5.1	Capella	217.7	ε Cygni	1.2
β Andromedæ	41.5	Pollux	166.1	Arcturus	6226.9
Polaris	188.5	η Herculis	6.4	Sun	1.0
α Arietis	58.9				

Two things strike the attention at once. First, the striking inferiority of the Sun to even the feeblest of these stars. This may be due, and not improbably is, to an under-estimate of its brightness. Or it may be due, and this is also not unlikely to be the case, to a general over-estimate of stellar distances. Next the great disparity in light-giving power of the various stars. Vega and Arcturus tower far beyond all the rest. Dr. Elkin's parallaxes have been used for both these stars, and in both cases he has found a much smaller value than his predecessors have done. Still, whilst making all allowances for the uncertainty of our knowledge of stellar parallax, the comparison seems to show that, if one class has the advantage over the other, the superioirty lies with the Solar stars; for including Vega and Arcturus, we find the mean first type star to have a radiation of 268.1, the mean second type of 544.0. Omitting those two stars, the figures become 45.6 and 70.5 respectively. Certainly no such deicded and unmistakeable superiority as we should naturally expect, is shown by the Sirian class.

Another and rougher method of comparison is to see how the stars of the two types are distributed for different orders of magnitudes. I have given a rough comparison in *Knowledge* for April last, which seems to show that Sirian stars become more numerous the fainter are the stars we are dealing with. This conclusion is confirmed by Professor Pickering's discovery that the Milky Way, which is especially a region of small stars, is especially rich in Sirian stars. It appears, then, either that Sirian stars are on the average smaller than Solar stars, or else that they are situated at greater distances from us.

Yet another mode of comparison is afforded us by double stars. Here we have two stars at the same distance from us; difference in apparent brightness is therefore equivalent to difference in real light-giving power. Unfortunately we know but little of the spectra of double stars, but, if in default of better information, we are guided by their colors, a very remarkable circumstance becomes apparent. Where the two stars are of the same color, they are always of the same, or nearly of the same, magnitude. But where they are of different colors, the difference of magnitude becomes much more marked; and in nearly every case the smaller star is blue, the larger one white or yellow. In a few cases the smaller star is not blue but red, but in no case is the larger star blue.

Accepting, as in some cases they certainly are, the yellow stars as of the Solar type, and the blue as Sirian, we are again brought

to conclude that so far from the Sirian stars being the largest and brightest, the very reverse is the case, and it is the Solar which have the better right to be entitled "Giant Suns."

It has been urged that the succession of the different stellar types might be just as plausibly taken in the reverse order, so that the Solar stars were they ounger, and not the Sirian. The conclusion just reached might be taken as confirming such a view, were it not for certain facts which strongly point to the first type stars being much less condensed than those of the second type. For in the case of binary stars, for which the elements of the orbit have been computed, we can compare, on the assumption that the intrinsic brightness per unit of surface for all the stars is the same, the density of one pair with that of another. The result, as the following table will show, gives 0.3026 as the mean density for the Solar class, the density of the Sun being taken as unity, and only 0.0211 for that of the Sirian. One most remarkable exception to the general greater density of Solar stars, however, is furnished by the instance of γ Leonis, which appears by this comparison as by far the lightest of all binaries, though it is of the second type. Still, even allowing for this evidently exceptional star, the Solar stars are on the average 14.3 times as dense as the Sirian, a difference too great and too systematic to be accidental. Further, Dr. Huggins has shown us stars actually involved in the great nebula of Orion, and showing the typical nebular lines; so that they would seem to be in the very process of forming out of the nebula. Yet the Orion stars are of the first type.

Sirian Stars.

OΣ 4	0.101	ω Leonis	0.022	ξ Scorpii	0.013
OΣ 20	0.006	θ Ursæ Maj	0.002	γ Ophiuchi	0.001
14 Orionis	0.022	γ Virginis	0.017	μ Draconis	0.021
12 Lyncis	0.003	25 Can. Ven	0.017	ζ Sagittarii	0.002
Sirius	0.011	η Coronæ Bor	0.109	δ Cygni	0.001
Castor	0.001	μ^2 Boötis	0.040	β Delphini	0.010
ζ Cancri	0.037	γ Coronæ Bor	0.002	λ Cygni	0.005

Solar Stars.

Σ 3062	0.323	42 Comæ	0.047	Σ 2107	0.079
η Cassiopeiæ	0.956	Σ 1757	0.803	Σ 2173	0.219
36 Andromedæ	0.012	Σ 1819	0.196	τ Ophiuchi	0.009
Σ 228	0.143	α Centauri	0.121	70 Ophiuchi	1.103
OΣ 149	0.164	γ Leonis	0.0002	γ Coronæ Aust	0.134
Σ 1037	0.073	ξ Boötis	0.914	OΣ 387	0.047
Σ 3121	1.882	44 Boötis	0.061	OΣ 400	0.034
ξ Ursæ Maj	0.181	OΣ 298	0.600	4 Aquarii	0.026
OΣ 234	0.075	α Coronæ Bor	0.077	τ Cygni	0.020
OΣ 235	0.059	ζ Herculis	0.018	π Cephei	0.005
				Sun	1.000

Further, the Algol variables, where we have a comparison star, revolving almost in contact with its primary, and we may infer, but recently separated from it, are all, so far as we know, of the first type. These stars are evidently in an early and but little condensed condition. So too, the "spectroscopic doubles" hitherto discovered, have all been of the first type. We may conclude, therefore, from such evidence as lies before us as yet, that if these two types of spectrum indicate successive stages of development at all, the ordinary idea that the Sirian is the earlier stage, must be accepted. And yet, as we have already seen, the Sirian stars should on that assumption have by far the greater total radiation; whereas the reverse would rather appear to be the case.

The colors of double stars emphasize this difficulty. If both members of a pair were formed at the same time, then the smaller should enter the earlier on the second stage of development, and we should expect to see many instances of Sirian primaries and Solar companions. And the greater the difference in size between the two, the further should the smaller body be advanced as compared with the larger. We really find the very reverse to be the case. We never find the primary blue and the satellite yellow; but the greater the difference in size between the two the more frequently is it the case that the principal star is yellow and its dependent blue. Nor can we get over the difficulty by supposing that the small star was formed much later than the larger. Whenever formed, it could not have started in an earlier state of condensation and temperature than its parent orb possessed at the time when it gave it birth.

Yet another fact has recently come to light which points yet more strongly in the same direction, viz., the prevalence in certain limited regions of special types of spectrum, such as those of the fourth type, or of the "Wolf-Rayet" stars, or fifth type. The discovery which Professor Pickering has now announced, that the Milky Way is specially rich in first type stars, is a fact of the same order; so also is the prevalence of a particular variety of that type in Orion. But the most conclusive circumstance of the kind is the discovery that the stars in the Pleiades are practically all of the same type. Forming, as they manifestly do, a real group, and therefore lying all, practically, at the same distance from us, and embracing amongst their number stars of a great range of magnitude, we see they must be of very different sizes. Yet we find practically but one type of spectrum. Is it reasonable to suppose that throughout the group the smaller stars are just so much younger in actual interval of time from their forma-

tion than the larger, that smaller size has been exactly balanced by shorter time and that in this way the entire group preserves to us an appearance of uniformity? Is it not much more natural to suppose that they all show the same spectrum, because, forming one group, they contain the same materials and in similar proportions?

There seems indeed to me but one way of reconciling all these different circumstances, viz., to suppose that spectrum type does not primarily or usually denote epoch of stellar life, but rather a fundamental difference of chemical constitution. If so, we can readily understand why special types should affect special regions, and why in the case of double stars the two should be of the same type when both are nearly of the same size, and the smaller the hydrogen star when the difference of magnitude is considerable. The spectroscope has indeed shown us that the same elements exist in Sun and stars as we are familiar with here, but to tack on to this fact the assumption, so often tacitly made, that they are distributed throughout the universe *in the same proportions*, seems to me wholly unwarranted and contrary to probability. If they are not thus equally distributed, then we ought to find some stars rich in hydrogen and some in metals, and the resulting differences in their spectra will afford us no ground for concluding the one to be in an earlier condition than the other. The difference will be one of chemical and fundamental constitution, not of epoch of stellar history.

Of course our knowledge on the various points to which I have alluded is as yet very meager, and further researches may entirely change the aspect of affairs. For example, we may find that our present types are far too general, we may be grouping together as of the same class of spectrum stars which a more careful examination may show to differ from each other in some easily overlooked but most important detail. Professor Pickering has already carried the classification of spectra much further than it has been carried before. So it may well turn out to be the case that there is only a superficial resemblance between the spectra of giants, like Sirius and Vega, and of the little stars which swarm in the galaxy, or of the tiny acolytes of unequal doubles. Lockyer has already urged a division of the solar type into two classes, one indicating a stage earlier than the Sirian, and the other later; an arrangement which would explain some of the facts I have here touched upon. But arguing from the facts we at present possess, I am inclined strongly to believe that the first and second types of spectrum indicate rather real differences of stellar constitution than differences in the stage of development.

The cases of the third and fourth types I consider different. We have much fewer facts to go upon with regard to them, but the evident connection between variability and third type spectrum inclines me to think that that class of spectrum, at least, may be really indicative of the particular stage in its history which the star has reached.

THE IRON SPECTRUM AS A COMPARISON SPECTRUM IN SPECTROGRAPHIC DETERMINATIONS OF STELLAR MOTION IN THE LINE OF SIGHT.*

PROFESSOR H. C. VOGEL,
DIRECTOR OF THE ASTRO-PHYSICAL OBSERVATORY, POTSDAM.

In the *Sitzungsberichten der. K. Akad. d. Wissenschaften* for March 15, 1888, an account is given of my first observations, by which it has been shown possible to reach a more certain basis for the determination of the motion of the stars in the line of sight by the spectrographic method than by direct observations, even with equal instrumental means. The expectations raised by these first results with a temporary apparatus as to the accuracy attainable in the determination of stellar motions, have not only been borne out in the course of time, but even much surpassed.

The more exact knowledge of the motions of the brighter stars in the northern sky, gained of late by spectrographic determinations, in general confirms the results of former direct observations as to the direction of the motion, but serves to considerably alter our notion of the velocity, which in the direct observations was generally much over-estimated.

I have given in *Astr. Nachrichten*, No. 2896, a description of the construction of the apparatus used to make final determinations, together with an account of the method of measuring spectrograms of stars of the second type. It was found very early in the course of the research that the accuracy of the results very largely depends upon the method of measuring the spectrograms; for this reason I have been busily engaged in ascertaining the most advantageous method. Great difficulties as to this point had to be overcome, especially in the case of stars of the first type with broad hydrogen lines, but even here I have succeeded in giving to the measures a precision nearly equalling that attained in stars of the second type. The method, which was described in

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* Translated from the *Sitzungsberichte der Berlin Akademie der Wissenschaften*, 4 June, 1891.

Astr. Nachrichten, No. 2995 with the account of the observations of α Virginis, is very simple, and at the same time secures to the observer the greatest possible freedom from prejudice. In all these investigations, however, the hydrogen spectrum, or rather the line $H\gamma$, has served as a basis for measurement.

In the autumn of 1888, when the first experiments with the new spectrograph were in progress, an endeavor was made to use another comparison spectrum in addition to the hydrogen spectrum. Magnesium naturally suggested itself, as the Mg line at wave-length $448\mu\mu$ is very sharp and clearly defined in a great many stellar spectra, and does not fall too far from the center of the portion of the spectrum given by the spectrograph. No satisfactory results have as yet been obtained in this way, however, as the Mg line artificially produced by the spark discharge in air is broad and diffuse, and is thus not suited for exact measures. The experiments were repeated with various modifications at the beginning of the present year, but with the same negative result. But the iron spectrum has turned out to be very useful for a comparison spectrum. The lines are sharp and not too numerous in the neighborhood of the $H\gamma$ and Mg ($448\mu\mu$) lines, so that for stars, in whose spectra this magnesium line is the only one visible in addition to the hydrogen line, measures may safely be made by connecting some iron lines with the magnesium line. But for bright stars of the first type, the spectra of which contain, in addition to the hydrogen line, a great number of fine lines mostly belonging to iron, there was reason to believe that a higher degree of accuracy might be reached in the determination of stellar motion in the line of sight by photographing the iron spectrum on the same plate with the spectrum of the star. For this purpose it is necessary that the iron lines do not cross the stellar spectrum, as I have found useful in the case of the hydrogen line, but extend only to its edges on either side. This result may be obtained by covering the part of the slit through which the image of the star passes with a small strip of metal, while the photograph of the iron spectrum is being taken. If this were not done it might happen that on account of their very small displacement, the lines of the artificial spectrum might fall too near the stellar lines, or even overlap them, so as to prevent accurate measures.

In the observations of Sirius recently made here the iron electrodes (piano-wire) were placed at a distance of 35cm from the slit, and were so adjusted that the short spark (2mm to 3mm) was exactly in the optical axis of the collimator. The spark was

produced by a large Ruhmkorff coil with 4 Leyden jars. An exposure of 25 seconds was sufficient to give the principal iron lines.

In addition to this, several points essential to accurate measures, to which I have called attention before, have been carefully observed. The comparison spectrum must be taken with the telescope directed to the star, and the middle of the exposures for the stellar and metallic spectra must coincide as closely as possible, in order to do away with the effect on the measures of changes in the flexure of the apparatus and variations in the dispersion due to temperature.

The following wood-cut gives an illustration (negative) of a portion of the spectrum of Sirius with the principal iron lines, as obtained on March 22, 1891. The cut was made from an enlarged copy of the original negative.*

Besides the lines of the iron spectrum, the artificially produced hydrogen line $H\gamma$ is seen extending across the spectrum of the star. All of the stellar lines, as compared with the corresponding lines of the artificially produced iron spectrum, show a slight displacement toward the red.

Measures of the plates under the microscope have given the following results:

March 21, 1891. Plate No. 246. Exposure for star = 48m. for Fe spectrum = 25s.		March 21, 1891. Plate No. 247. Exposure for star = 15m. between clouds, for Fe spectrum = 60s.		March 22, 1891. Pltae No. 248. Exposure for star = 36m for Fe spectrum = 25s.	
λ	Δ R	λ	Δ R	λ	Δ R
426.1	0.070 (1)	428.3	0.026 (1)	426.1	0.036 (2)
428.3	0.064 (1)	429.5	0.044 (2)	427.2[1]	0.042 :(2/3)
429.5	0.044 (2)	430.0	0.037 (2)		0.036 (1)
430.8	0.056 (2)	430.8[3]	——	428.3	0.047 (1)
432.6	0.049 (2)	431.6	0.044 (2)	429.5	0.036 (2)
435.2[2]	0.039 (0)	436.8	0.035 (1)	430.0	0.026 (1)
438.4	0.044 (2)	437.6	0.045 (1)	430.8	0.019 (2)
440.5	0.033 (1)	438.4[4]	——	431.6	0.033 :(2/3)
		440.5	0.040 (2)	432.6	0.024 (2)
		441.5	0.033 (1)	438.4	0.027 (2)
		442.3[5]	0.044 (1)	440.5	0.020 (1)
				441.5	0.024 :(2/3)

[1] Double line, the first component very faint in the star spectrum. [2] As it is doubtful whether the stellar and iron lines correspond the observation is omitted. [3] Lines of the iron spectrum too broad and strong for a good measure. [4] Lines in the iron spectrum too broad and strong, in the star diffuse and not well seen. [5] Iron line very faint.

* Much of the perfection of detail in the original has unfortunately been lost in the reproduction. The hydrogen line in the star should be very diffuse at the edges, not sharply defined as shown. [G. E. H.]

The first column gives the wave-lengths in millionths of a millimetre, the second the measured distances between the lines in the stellar spectrum and the corresponding lines of the comparison spectrum in turns of the micrometer screw ($1^R = 0^{mm}.25$). The value of the distance measure obtained as the mean of 4 settings has a weight 1. In the case of particularly well defined lines two sets of independent measures have been made; the mean of these measures is given the weight 2, while the weight ⅔ designates observations of lines which were measured with difficulty.

In the photographs of March 21 the stellar spectra are narrow, and the lines of the iron spectrum do not extend to the edges of the spectrum of the star. In measures of the star spectrum the settings were made tangential to the curved lines, while in the case of the iron spectrum the ends of the arcs above and below the star spectrum were united by the cross-hair, thus rendering necessary a correction to the measures. The mean of several measures in the neighborhood of the $H\gamma$ line gave 266^R as the radius of curvature of the lines in the spectrum, and thus corrections of $0^R.008$ and $0^R.005$ are deduced for the distance of the point of tangency from the middle of chords $4^R.0$ (No. 246) and $3^R.3$ (No. 247) in length respectively. Since the lines are convex toward the red end of the spectrum, and the displacement of the stellar lines as referred to the comparison lines is in the same direction, it follows that all measures will be diminished by this amount. In the photograph of March 22 the iron lines reach to the edges of the star spectrum. In the measures the settings were made on the points of contact, and on the stellar lines also at the edge of the spectrum, so that no correction is necessary.

The amount of the linear displacement in different regions of the prismatic spectrum is different for equal differences of wave-length, or the same displacement corresponds to a different velocity in the line of sight. For the wave-lengths in question the motions in geographical miles may be found in the following table, which has been determined from numerous measures of photographs of the solar spectrum made with the spectrograph.

$\lambda = 426\ \mu\mu$	$1^R = 27.5$ geogr. M.
428	28.1
430	28.7
432	29.4
434	30.2
436	30.9
438	31.7
440	32.5

Applying the correction for the curvature of the lines the motions of Sirius corresponding to the displacements as calculated from the table are as follows:

λ	March 21, No. 246. Δ (geogr. miles.)	March 21, No. 247. Δ (geogr. miles.)	March 22. No. 248. Δ (geogr. miles.)
426.1	1.71 (1)	—	0.99 (2)
427.2	—	—	1.17 (⅔) 1.01 (1)
428.3	1.58 (1)	0.59 (1)	1.33 (1)
429.5	1.03 (2)	1.12 (2)	1.03 (2)
430.0	—	0.92 (3)	0.75 (1)
430.8	1.39 (2)	—	0.55 (2)
431.6	—	1.14 (2)	0.97 (⅔)
432.6	1.21 (2)	—	0.71 (2)
436.8	—	0.94 (1)	—
437.6	—	1.26 (1)	—
438.4	1.15 (2)	—	0.86 (2)
440.5	0.82 (1)	1.14 (2)	0.65 (1)
441.5	—	0.93 (1)	0.79 (⅔)
442.3	—	1.30 (1)	—
Mean:	1.24	1.05	0.87

The mean of the three determinations, considered as of equal weight, is 1.05 geographical miles, which is the amount per second by which the star increases its distance from the Earth, as the displacement of the lines in the spectrum is toward the red. At the time of the observation the component of the Earth's motion in the direction of Sirius was + 3.01 geographical miles. The motion per second of Sirius with respect to the Sun on March 22.0, 1891, was therefore:

— 1.96 geogr. miles.

I give below the observations of the motion of Sirius obtained with the spectrograph, in which the measures of displacement were made with respect to the hydrogen line $H\gamma$.

Date.	Observed Displacement in revolutions of the screw.	Motion of Sirius with respect to Earth. geogr. miles.	Reduction to Sun. geogr. miles.	Motion of Sirius with respect to Sun. geogr. miles.
1888 Dec. 1	−0.110	−3.32	+1.64	−1.68
Dec. 13	−0.103	−3.11	+1.06	−2.05
Dec. 13	−0.101	−3.05		−1.99
1889 Feb. 10	+0.023	+0.69	−1.95	−1.26
1890 Jan. 29	−0.004	−0.12	−1.42	−1.54
Feb. 12	+0.022	+0.66	−2.04	−1.38
Feb. 12	+0.006	+0.18		−1.86
1891 Feb. 7	+0.001	+0.03	−1.81	−1.78
Mar. 21	+0.032	+0.97	−3.00	−2.03
Mar. 22	+0.044	+1.33	−3.01	−1.68
				Mean: −1.73

The agreement of this mean with the value deduced above is certainly very satisfactory, and in this case the use of the iron spectrum is of little advantage, especially if it is considered that

much more physical apparatus is needed for the observation. Great accuracy is also required in the adjustment of the electrodes, in order that the spark may be as nearly as possible in the optical axis of the telescope, while the adjustment of the hydrogen Geissler tube at right angles to the optical axis does not require particular care, if the tube is accurately placed at right angles to the direction of the slit. That the advantage of using the iron spectrum is not clearly brought out in the case of Sirius is principally due to the circumstance that the lines in the Sirius spectrum are so very faint and narrow that settings of the micrometer cross-hair cannot be made with as great accuracy as with somewhat broader and stronger lines. The photographs on March 21 and 22 of this year are also not as good with respect to the fine lines as others obtained before. α Cygni would have served better, as the iron lines in its spectrum are stronger.

The principal advantage of the method, which must not be overlooked, lies in the fact that each line, compared with the corresponding line of the artificial spectrum, gives an independent determination of the motion; thus the value of a single plate is much increased, as in the method which I have used for spectra of the second type, for the effect of any irregularities in the photographic film is eliminated by measuring several lines.

The iron spectrum is also recommended as a comparison spectrum for stars of the second type, but in these spectra containing a great number of lines mistakes are more easily made in comparing the stellar lines with the corresponding artificial lines than is the case with stars of the first type, particularly those which show only iron lines, and great care is therefore necessary in the choice of the lines. This caution may even be carried so far as to omit narrow double lines with very unequal components, for I have found that in photographs of emission spectra an unsymmetrical widening occurs in very close double lines, such that after long exposure the centers of the photographed lines are more widely separated, since the deposit of silver is greater on the outer edges than between the lines. When the components are equal this peculiarity of the photographic plates does no harm, if the measures are made on the middle of the double lines. Even in absorption spectra a very similar propensity to that seen in emission spectra is to be expected, though perhaps to a less extent, and in fact it has been found in a great number of measures in the spectra of stars of the second type which contain a great many lines, that large deflections are most frequent in the case of close double lines with unequal components. Single lines have therefore been used as far as possible in the measures.

I may add in conclusion that with the investigations on Sirius here presented my preliminary spectrographic observations for the determination of stellar motions are ended for the present; but I hope that I will be able to resume them shortly with more powerful optical apparatus.

RESEARCHES ON THE RADIAL MOTION OF STARS WITH THE SIDEROSTAT OF THE PARIS OBSERVATORY.*

M. H. DESLANDRES.

The investigation of the radial velocity† of stars by the displacement of lines in their spectra, according to the method of M. Fizeau, must furnish the solution of new and important questions. But the experiment is a delicate one, and twenty-five years of visual observations of these displacements has given only uncertain or contradictory results; photographic observation, on the contrary, does not seem to be subject to the same sources of error. It is my intention, according to the plan of Admiral Mouchez, to carry on at the Paris Observatory the regular study of stellar motions by spectrum photography.

The first results were obtained with the great telescope of 1.20 metres aperture (see *Comptes rendus*,1891); but the spectroscope employed, which was then the only one which could be adapted to this great instrument, was of small dispersive power (a displacement of $\frac{1}{200}$ millimetre corresponding to a velocity of 11 kilometres per second). I have also used for the same purpose the Foucault siderostat, with which any form of spectroscope may be readily employed.

Method of Experiment.—The beam of light reflected horizontally by the mirror of the siderostat is received by a 12-inch objective (Secrétan),‡ which gives an image of the star on the slit of the spectroscope. The spectroscope, arranged for photography, has 1 or 2 prisms of light flint, with lenses of 0.65 metre focal length. A displacement of $\frac{1}{200}$ millimetre corresponds, with one prism, to a velocity of 8 kilometres per second; with two prisms, to a velocity of 5 kilometres.

But the siderostat has no finder, and follows the diurnal

* "Comptes rendus" November 23, 1891.

† I call *radial velocity* the velocity projected on the radius which unites the earth to the star. This velocity, as is well known, is not given by ordinary observations, which can only reveal the component perpendicular to the radius.

‡ This objective was formerly employed on the equatorial of the West tower; I have achromatized it for the chemical rays by a suitable separation of the lenses.

motion very badly. I have had recourse to a special method of directing and maintaining the star on the slit. This slit, which is illuminated by a red light, is formed of two platinum jaws, polished and inclined in such a manner as to reflect to one side the beam of light from the objective. An auxiliary telescope, placed near the right ascension and declination slow motions, receives this light, and gives the image of the star and the slit in the same field of view. It is thus possible to correct the irregular movement of the siderostat.* As a further precaution another auxiliary telescope receives the rays reflected from the first prism, and indicates at any instant the quantity of light which enters the spectroscope.

At the middle of the exposure the comparison spectra are photographed above and below the spectrum of the star, the two sources to be compared being placed in as nearly as possible identical conditions. The sources of comparison are electric sparks from at least three substances, hydrogen, calcium and iron, which are found in most of the heavenly bodies. The electric spectrum of iron, which I was the first to employ and recommend (*Comptes rendus*, 1890 and Feb., 1891), is particularly advantageous on account of the numerous fine lines which it contains; for the investigation of displacement it is much to be preferred to the single line $H\gamma$ of hydrogen, employed by M. Vogel; with white stars of the first type, it assures twice as great precision to the measures. Moreover, in a recent note,† M. Vogel announces that on the 21st of last March he tried the iron spectrum and recognized its superiority.

Results.—These simple arrangements have allowed photographs and measures of displacement to be made of the brighter stars. I have the honor to present to the Academy one of these photographs, which shows the spectrum of Sirius compared March 3, 1891, with the spectra of hydrogen, iron and calcium.

The photograph shows at a glance that 4 lines of hydrogen, 2 of calcium and 11 of iron are present in the star. Moreover, the lines of the star, referred to the comparison lines, are slightly displaced towards the red. This displacement, measured to $\frac{1}{200}$ millimetre on the 10 sharpest lines, corresponds to an apparent receding motion of the star of + 19 kilometres per second. Now the velocity of the earth in its orbit, projected on the direction of

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* The irregularities are largely due to the nature of the apparatus; four movements of rotation take place around four different axes, and these, with an additional sliding motion, must be simultaneous. Moreover, the correcting movements are insufficient.

† See page 151.

Sirius, is + 20.2 kilometres. Thus on March 3 Sirius was moving towards the Sun with a velocity of — 1.2 kilometres.

These results show the aid that may be derived from the siderostat for the study of the chemical composition and motions of the bright stars; a future note will describe a new arrangement of the great telescope of 1.20 metres aperture for the study of fainter stars with high dispersion.

NOTE ON RECENT SOLAR INVESTIGATIONS.

GEORGE E. HALE.

On December 28, 1891, photographs made at this Observatory showed that the H and K lines are reversed, not only in the vicinity of Sun-spots, but in regions irregularly distributed over the entire disc of the Sun. On January 12, 1892, it was found possible to photograph the *forms* of some of these reversed regions, using a moving slit apparatus just completed for our large diffraction spectroscope by Brashear. The K line in the fourth order spectrum was employed, as is customary in the case of prominences. The reversed regions are of great extent, and in appearance closely resemble faculæ. Several explanations may be suggested to account for them. They may be:

1. Ordinary prominences projected on the disc.
2. Prominences in which H and K are bright, while the hydrogen lines are absent.
3. Faculæ.
4. Phenomena of a new class, similar to faculæ, but showing only H and K bright, and not obtained in eye observations or ordinary photographs because of the brilliant background upon which they are projected.

The investigation will be continued as rapidly as the present unfavorable atmospheric conditions will permit.

Kenwood Astro-Physical Observatory,
Chicago, January 18, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in Astro-Physics should be addressed to George E. Hale, Kenwood Astro-Physical Observatory, Chicago, U. S. A. Authors of papers are requested to refer to page 176 for information in regard to reprint copies, etc.

In addition to the letters from well-known astronomers and spectroscopists which were printed in our last number, others expressing interest in Astro-Physics, and promising support, have been received from Dr. B. Hasselberg, Stockholm, Professor N. C. Dunér, Upsala, and Dr. Ralph Copeland, Astronomer Royal for Scotland. The latter has been kind enough to make arrangements such that important papers communicated by the staff of the Royal Observatory to the Edinburgh Royal Socieiy, will be found at an early date in these columns. Professor Hasselberg will soon publish a paper in Astro-Physics on his recent investigations, and other important articles may be expected from Herr Victor Schumann and Herr J. Plassmann.

Effect of Aberration on Measures of Solar Prominences. On pages 126 and 128 translations are given of the papers on aberration by MM. Fizeau and Mascart, which were referred to by Dr. Crew in the last number of Astronomy and Astro-Physics. Dr. Crew has done a service in pointing out the error in M. Fizeau's paper, for though the question cannot be considered as in any degree difficult, it is at the same time somewhat misleading, as such an error on the part of so distinguished a specialist as M. Fizeau sufficiently testifies. We must ourselves confess to having been deceived on this point, but wickedly find a crumb of comfort in the thought that the editors of the *Observatory* and other well-known publications were equally unfortunate.

Photographs of the Recent Total Eclipse of the Moon. In the *Comptes rendus* for November 23, M. G. Rayet gives the results of observations made at Bordeaux of the total lunar eclipse, which occurred on Nov. 15, 1891. In spite of unfavorable atmospheric conditions it was found possible during totality to photograph a considerable portion of the Moon's disc with an exposure of about two minutes. The instrument employed was the photographic equatorial of 33 centimeters aperture. In his remarks on M. Rayet's communication, M. Janssen suggests that a measure of the photographic value of the light from the totally eclipsed Moon might be obtained by finding the time required to give, on a portion of the plate used in photographing the eclipse, an image of the full Moon of the same intensity. The ratio of the times of exposure would give the inverse ratio of the photographic intensities. As the light reflected from the Moon during eclipse must pass through a great depth of the earth's atmosphere M. Janssen hoped to observe the faint oxygen absorption bands in the green and blue regions of its spectrum, but observations at Meudon were unfortunately prevented by bad weather.

Herr Schumann's Discoveries in the Ultra-Violet Hydrogen Spectrum. In a letter dated Dec. 10, 1891, Herr Schumann sends us a most interesting account of his recent important discoveries in the extreme ultra-violet. During a visit to his laboratory in Leipzig last summer we were greatly struck by the extreme neatness and attention to detail there apparent. Under a microscope the photographs of gaseous and metallic spectra showed a sharpness of definition which has probably never been equalled in work of a similar degree of difficulty. For his extensive investigations of the hydrogen spectrum Herr Schumann has not less than one hundred tubes, most of them fitted with quartz stoppers for end-on illumination, and his collection of quartz and fluor spar prisms and lenses is remarkably large.

In no region of the spectrum does the investigator encounter such great difficulties as in the extreme ultra-violet, for not only do these short waves exercise but little effect upon the most carefully prepared photographic plates, but in addition they are completely absorbed by a layer of air of only a few feet in thickness. For this reason, in passing beyond λ 1800, Herr Schumann finds it necessary to use his spectrograph in a vacuum. After working an entire year he has succeeded in preparing photographic plates by a new formula, which possess an extraordinary degree of sensitiveness. They also have the peculiar property of becoming more sensitive the longer they are kept, without being subject to any of the defects which ordinary bromide of silver plates acquire under the same conditions.

A few weeks preceding the date of his letter, working with his new plates on the spectrum of hydrogen, Herr Schumann succeeded in photographing several centimetres beyond the most advanced ultra-violet boundary line then known. In the most refrangible part of this extremely feeble region, but one plate was sufficiently sensitive to show any trace of action. All other plates, though made by the same formula, were not acted upon in the least, even after very long exposure. With the highly improved apparatus then used the attempt was made to resolve the group of hydrogen lines beyond λ 1820 discovered by the same investigator in the preceding year. The results greatly surpassed his expectations, for the group was not only perfectly resolved, but found to contain many more lines than had been supposed from the photographs of 1890. Beyond λ 1820 fourteen clearly defined groups were found, all of them containing a remarkably large number of lines. The first group, which is only 11^{mm} long on the plate, and was made with a slit 0.004^{mm} wide, contains *over 90* well defined lines. The other groups are hardly so rich in lines, but altogether contain about 600. It is thus evident that the radiation of incandescent hydrogen in the hitherto unknown region beyond λ 1820 is surprisingly great.

It is unfortunate that the nature of the apparatus, supplied as it is with fluor spar prisms and used in a vacuum, will not allow the wave-lengths of the most refrangible lines reached to be determined. For this purpose it is hoped that a Rowland concave grating, which is very brilliant in certain spectra, may be used. With this grating the aluminium lines at λ 1860 and λ 1852 have been photographed through a layer of air two metres thick in 45 minutes, a primary current of only seven amperes being employed, while the plates were prepared after the new formula. It has been found impossible with any other plates to photograph these lines through an equal thickness of air, though with the grating this may be accomplished with ordinary silver bromide plates. The remark is made, in passing, that the line at λ 1929, assigned by Cornu to aluminium, belongs in fact to silicon, as has been found by extensive investigation.

A further peculiarity is recorded in the fact that the lines λ 1860 and λ 1852 show a different relative intensity, according as the grating or prisms, whether quartz or fluor spar, are used. The grating gives the more refrangible line of much less intensity than the other, while with prisms the lines are equal in intensity. As yet a lack of time has prevented an investigation of the cause of this difference. It may be due to atmospheric absorption, but it is also possible that the speculum metal may absorb the short waves more strongly than the long. The general absorption of the speculum metal may change at this point into a selective absorption, such that the more refrangible line would be much weakened.

In the construction of the new spectrograph the camera will be so arranged

that it can be set at any desired angle to the optical axis of the lens. In the present instrument the camera is fixed at a constant angle of 26°, which is suitable for the region between λ 1860 and λ 1820. For waves shorter than these, the angle must be very much smaller in order to secure the best definition.

The Chromosphere Line Angstrom 6676.9. In *Nature* for Dec. 31, 1891, Professor Young thus replies to the Rev. Cortie's letter on page 135.

"In response to Father Cortie's implied question as to the identification of this line as belonging to the spectrum of iron, I would refer him to Appendix G of Roscoe's lectures on "Spectrum Analysis" (third edition). It is an extract from a joint paper by Ångstrom and Thalen, giving a list of several hundred (then) new identifications; among them appears K 654.3, ascribed to iron.

"The original memoir was presented to the Stockholm Academy of Sciences in February, 1865, and an English translation appeared the next year. I am unable to assign any reason why many of the identifications given in this memoir fail to appear in the map published three years later; but they do, and K 654.3 is among the missing."

Observations of Sun-spot Spectra. On another page we reprint from the Journal of the British Astronomical Association, a paper by the Director of the Solar Spectroscopic Section, the Rev. Walter Sidgreaves. Those who propose to take up spectroscopic work on the Sun will find in this article many valuable suggestions. Though the fact that the possessors of even very small telescopes can secure valuable results in the study of the Sun has been fully demonstrated by several members of the British Astronomical Association, the impression still seems to be very general that spectroscopic work of any kind cannot be done without the most elaborate and costly apparatus. For this reason many amateur observers with small instruments may be found engaged in planetary, lunar, or stellar observation, while very few ever consider the really important contributions they might easily make to Astro-Physics, without expensive additions to their equipment. At the present time, the spectra of Sun-spots offers a most promising field for investigations with small instruments. Of the two or three engaged in a systematic study of the lines affected in spots, the Rev. Sidgreaves is the most active observer, but the observations at Stonyhurst are necessarily confined to a small portion of the spectrum, and at South Kensington the investigation is even more limited in extent. Many more observers are needed at once for this work, for some of the most important questions in solar physics may find their answers in the statistical study of data thus obtained. A telescope of 4 inches aperture or even less is large enough for the purpose, and, if possible, some sort of driving mechanism should be used, such as a sand-clock, air-bag and weight, water-clock, or similar simple contrivance. As the Rev. Sidgreaves points out, however, observations may be made even without a driving-clock. But we imagine that to many the most serious question will be as to the spectroscope. No difficulty should be anticipated on this point, for a very satisfactory instrument can easily be put together at a very small expense. A suitable frame can be made of wood, and adapted to the telescope. On it two little telescopes of perhaps an inch aperture should be fixed at an angle of 25° or less, and one of them, which is to act as the collimator, must have at its eye-end a simple adjustable brass slit, on which the image of the Sun formed by the large telescope is brought to a focus. The only thing necessary to complete the spectroscope for observing solar prominences or spot spectra is a small reflecting grating, which must be so supported that it can be rotated around an axis through the point of intersection of the optical axes of the collimator and observing telescope, and at

right-angles to the plane in which they lie. Such a grating, ruled by Rowland, and therefore of the best quality, can be obtained for about fifteen dollars. It is greatly to be hoped that some amateur observers will take up the study of spot-spectra, and they may be certain of the most fruitful results as the reward of careful investigation.

We heartily recommend to our readers Part XII of Old and New Astronomy, which has recently been brought out by Mr. A. Cowper Ranyard. It will be remembered that at Mr. Proctor's death Mr. Ranyard took up the task of editing "Knowledge," and also that of completing the partly finished volume of Old and New Astronomy. Certainly all astronomers owe a debt of gratitude to Mr. Ranyard for the beautiful reproductions of recent photographs of celestial objects which have been published in "Knowledge." Some of these appear as most fitting illustrations in Old and New Astronomy, and bring out very clearly the prominence-like forms in the Great Orion Nebula, and the remarkable dark structures in the Milky way.

We refer to the book for an interesting discussion of the nature of the Milky Way, where the conclusion is reached that this great structure is much nearer to us than has been supposed. The probability is also pointed out that there is absorption of light in space. In addition to many other interesting points which the author's papers in "Knowledge" have made familiar, the discussion of proper motions is given considerable space, and a reason is offered for the large average proper motions of the smaller stars.

Old and New Astronomy will soon be completed by the publication of Part XIII, which will also contain the index.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS DURING MARCH.

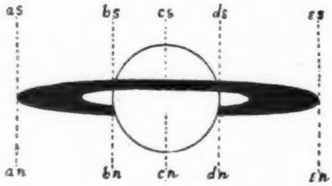
Mercury will be at superior conjunction with the Sun, March 5 at midnight. It will, therefore, for the first half of the month be invisible behind the Sun. Toward the middle of the month it will be far enough east from the Sun for daylight observations with large telescopes, and at the end of the month will be visible to the eye after sunset. Greatest eastern elongation, 19° 03′, occurs March 30, when the planet will set two hours later than the Sun. Mercury and Jupiter will be in conjunction, only 14′ apart in declination, March 12 at 2^h 53^m P. M., central time.

Venus, during March, will be in excellent position for observation. She is moving rapidly northward so that her meridian passage will be at a high altitude, and this, occurring at a little before three o'clock in the afternoon, will give opportunity for both day and evening observations at favorable altitudes. The diameter of the disk of Venus will be 15″ March 1, and 18″ March 31. The illuminated portion of the disk will be 0.760 of the whole on the first and 0.650 on the last day of the month. The brilliancy of this most brilliant of the planets will increase during the month from 81 to 103 on the scale given in the American Ephemeris.

Mars is a morning planet yet, rising in the southeast a little before 3 o'clock. His declination is 23° south, so that he will not be in very good position for observation during March.

Jupiter will be in conjunction with the Sun March 20, so that no observations will be possible during this month.

Saturn will be at opposition March 16, so that his position during this month is the most favorable for observation. This planet is in the constellation Virgo between the stars β and η, being considerably brighter than any of the stars in the vicinity. For chart of path among the stars see page 81 of the January number of this journal.



The rings of Saturn are still very nearly edgewise toward the earth. At present their apparent width is decreasing and will decrease from 1.88″, March 1, to 0.26″ May 25, after which it will increase slowly. Valuable observations upon the relative brightness and thickness of the two *ansæ* of the rings may be made by careful observers during these months. The relative thickness of the *ansæ* and of the shadow of the rings on the face of the planet should also be carefully determined. Sharp lookout should also be kept for the shadows of the satellites and any markings which may be detected upon the face of the planet and which may serve to determine the rotation period. A number of small dark spots were observed last year by Mr. A. S. Williams in England. The accurate determination of the times when the satellites are in conjunction with the ends of the ring, the center and extremities of the planet's equatorial diameter, in the positions indicated by the accompanying diagram, *an, as, bn, bs, cn, cs, dn, ds, en* and *es*, will be of great value in determining the corrections to the elements of the satellite orbits. The predicted times of these conjunctions are given in Mr. Marth's ephemeris p 166.

Uranus is in the eastern part of Virgo near the star λ, with which it will be in conjunction March 18 at about 7 P. M., central time. Uranus will then be only about 1′ 20″ north of the star. This will be an excellent opportunity for the possessors of small telescopes to identify the planet, for it will be quite near the star λ Virginis for several days. For chart of the constellation Virgo and path of Uranus, see our last number, page 81.

Neptune will be above the western horizon during the evening hours of March, a little north of the V-shaped group of stars, the Hyades, of which the first magnitude red star Aldebaran, is the principal star. For chart of his path, see SIDEREAL MESSENGER, Nov. 1891, p. 463.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Mar. 5......	23 8.2	−17 24	6 38 A. M.	12 12.3 P. M.	5 46 P. M.
15......	0 18.5	+ 1 34	6 33 "	12 43.0 "	6 53 "
25......	1 22.4	+10 23	6 23 "	1 7.6 "	7 53 "
			VENUS.		
Mar. 5......	1 31.7	+ 9 59	7 52 A. M.	2 35.5 P. M.	9 19 P. M.
15......	2 15.8	+14 41	7 37 "	2 40.1 "	9 43 "
25......	3 00.6	+18 49	7 24 "	2 45.4 "	10 07 "
			MARS.		
Mar. 5	17 38.7	−23 16	2 19 P. M.	6 43.8 A. M.	11 09 A. M.
15......	18 04.7	−23 32	2 08 "	6 30.5 "	10 52 "
25......	18 30.5	−23 35	1 54 "	6 16.7 "	10 39 "
			JUPITER.		
Mar. 5......	23 51.8	− 2 04	7 01 A. M.	12 55.9 P. M.	6 51 P. M.
15......	0 00.6	− 1 06	6 26 "	12 25.4 "	6 25 "
25......	0 08.6	− 0 14	5 52 "	11 54.9 A. M.	5 58 "

SATURN.

Date 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Mar. 5	11 55.2	+ 3 14	6 41 P. M.	12 57.3 A. M.	7 13 A. M.
15	11 52.4	+ 3 33	5 58 "	12 15.1 "	6 32 "
25	11 49.5	+ 3 52	5 14 "	11 32.9 P. M.	5 52 "

URANUS.

Mar. 5	14 14.6	−12 58	10 05 P. M.	3 16 3 A. M.	8 28 A. M.
15	14 13.6	−12 53	9 24 "	2 36.0 "	7 48 "
25	14 12.3	−12 46	8 43 "	1 55.4 "	7 08 "

NEPTUNE.

Mar. 5	4 19.1	+19 50	9 56 A. M.	5 22.4 P. M.	12 49 A. M.
15	4 19.6	+19 52	9 17 "	4 43.7 "	12 11 "
25	4 20.4	+19 54	8 38 "	4 05.1 "	11 32 P. M.

THE SUN.

Mar. 5	23 07.1	− 5 39	6 29 A. M.	12 11.5 P. M.	5 54 P. M.
15	23 44.0	− 1 44	6 11 "	12 8.8 "	6 06 "
25	0 20.4	+ 2 13	5 53 "	12 5.8 "	6 19 "

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl .... $+ 81°\ 17'$
Period .... $2d\ 11^h\ 50^m$

Mar. 2	10 P. M.
7	10 "
12	9 "
17	9 "
22	9 "
27	8 "

ALGOL.

R. A. .... $3^h\ 01^m\ 01^s$
Decl .... $+ 40°\ 32'$
Period .... $2d\ 20^h\ 49^m$

Mar. 4	midn.
7	9 P. M.
10	6 "
22	5 A. M.
25	2 "
27	11 P. M.
30	8 "

R CANIS MAJ.

R. A. .... $7^h\ 14^m\ 30^s$
Decl .... $- 16°\ 11'$
Period .... $1d\ 03^h\ 16^m$

Mar. 3	6 P. M.
4	10 "
11	6 "
12	9 "
13	midn.
19	4 P. M.
20	8 "
21	11 "
28	7 "
29	10 "

S CANCRI.

R. A. .... $8^h\ 37^m\ 39^s$
Decl .... $+ 19°\ 26'$
Period .... $9d\ 11^h\ 38^m$

Mar. 6	6 A. M.
15	6 P. M.
25	5 A. M.

δ LIBRÆ.

R. A. .... $14^h\ 55^m\ 06^s$
Decl .... $- 8°\ 05'$
Period .... $2d\ 07^h\ 51^m$

Mar. 12	2 A. M.
19	1 "
26	1 "

U CORONÆ.

R. A. .... $15^h\ 13^m\ 43^s$
Decl .... $+ 32°\ 03'$
Period .... $3d\ 10^h\ 51^m$

Mar. 2	5 A. M.
9	3 "
15	midn.
22	10 P. M.
29	8 "

U OPHIUCHI.

R. A. .... $17^h\ 10^m\ 56^s$
Decl .... $+ 1°\ 20'$
Period .... $0d\ 20^h\ 08^m$

Mar. 3	6 A. M.
4	2 "
9	3 "
9	11 P. M.
14	3 A. M.
14	11 P. M.
19	4 A. M.
19	midn.
24	5 A. M.
25	1 "

U OPHIUCHI, CONT.

Mar. 29	6 A. M.
30	2 "

S ANTLIÆ.

R. A. .... $9^h\ 27^m\ 30^s$
Decl .... $- 28°\ 09'$
Period .... $0d\ 07^h\ 47^m$

Mar. 2	1 A. M.
2	midn.
3	11 P. M.
4	11 "
5	10 "
6	9 "
7	9 "
8	8 "
9	7 "
10	7 "
11	6 "
12	5 "
13	1 A. M.
13	midn.
14	midn.
15	11 P. M.
16	10 "
17	9 "
18	9 "
19	8 "
20	7 "
21	6 "
22	6 "
23	5 "
24	1 A. M.
25	1 "
25	midn.
26	11 P. M.
27	10 "
28	10 "
29	9 "
30	8 "
31	7 "

Mr. Marth's Ephemerides of the Satellites of Saturn.

[From *Monthly Notices*, Nov. 1891.]

In this table the times have been changed from Greenwich Mean Time to Central Standard Time. The abbreviations *Rh.*, *Te.*, *Di.*, *En.*, and *Mi.*, stand for the names of the satellites Rhea, Tethys, Dione, Enceladus, and Mimas. The letters *a*, *b*, *c*, *d*, and *e*, stand for conjunctions of the satellites in order as follows: With the preceding end of the outer ring; with preceding end of planet's equatorial diameter; with center of planet; with following end of planet's diameter; with following end of ring. The letters *n* and *s* signify that the satellite at the time of conjunction is north or south of the point designated by the preceding letter; *Sh.* means that the shadow of a satellite is near the central meridian of the planet; *Ecl. D.* and *Ecl. R.*, the disappearance and reappearance of a satellite at beginning and end of an eclipse.

Feb. 1892.		
15	11.9 pm	En as
16	12.1 am	Di ds
	12.8	Te es
	1.3	Di Sh
	2.8	Te ds
	3.4	Mi an
	3.4	Di bs
	3.9	Te Sh
	5.6	Di as
	5.7	Te bs
	4.3 pm	En en
	4.7	Rh es
	7.2	Rh ds
	8.4	Rh Sh
	8.6	Mi as
	9.0	Titan an
	10.4	Titan Ecl. D
	11.1	Rh bs
	11.4	Te an
17	1.1 am	Te Ecl. D
	1.7	Rh as
	2.0	Mi an
	2.4	En es
	3.1	Titan Ecl. R
	3.8	Titan c9 .3n
	4.3	Te dn
	6.3	Te en
	6.7	Titan dn
	6.7	Di an
	2.4 pm	Di en
	6.8	En an
	7.2	Mi as
	10.1	Te es
18	12.1 am	Te ds
	12.6	Mi an
	1.2	En en
	1 3	Te Sh
	3.0	Te bs
	5.0	Te as
	3.6 pm	Di es
	5.6	En as
	5.8	Di ds
	5.8	Mi as
	7.0	Di Sh
	8.7	Te an
	9.1	Di bs
	10.4	Te Ecl. D
Feb. 1892.		
18	10.8 pm	Rh an
	11.2	Mi an
	11.3	Di as
19	12.7 am	Rh Ecl. D
	1.6	Te dn
	3.6	Te en
	3.7	En an
	5.1	Mi en
	5.3	Rh dn
	4.4 pm	Mi as
	7.4	Te es
	8.1	En es
	9.4	Te ds
	9.8	Mi an
	10.6	Te Sh
20	12.3 am	Te bs
	12.4	Di an
	2.2	Di Ecl. D
	2.3	Te as
	2.5	En as
	3.7	Mi en
	5.9	Di dn
	6.0 pm	Te an
	6 9	En en
	7.7	Te Ecl. D
	8.4	Mi an
	10.9	Te dn
21	12 9 am	Te en
	2.3	Mi en
	5.0	Rh es
	5.0	En es
	2 0 pm	Rh as
	2.7	Di bs
	4 7	Te ds
	4.9	Di as
	6 7	Te ds
	7.0	Mi an
	7.9	Te Sh
	9.5	En an
	9.6	Te bs
	11 6	Te as
22	12.9 am	Mi en
	3.8	En en
	3.3 pm	Te an
	5.0	Te Ecl. D
	5.7	Mi an
	6.0	Di an
Feb. 1892.		
22	7.9 pm	Di Ecl. D
	8.2	Te an
	8.2	En as
	10.2	Te en
	11.5	Di dn
	11.6	Mi en
23	1.7 am	Di en
	1.2 pm	Rh Ecl. D
	2.0	Te es
	4.0	Te ds
	4.3	Mi an
	5.2	Te Sh.
	5.6	Rh dn
	6 9	Te bs
	8.2	Rh en
	8.9	Te as
	10.2	Mi en
	10.8	En es
24	2.9 am	Di es
	3.6	Mi es
	5.1	Di ds
	5.1	En as
	12.9 pm	Titan es
	2.4	Te Ecl. D
	2.9	Mi an
	3.2	En an
	4.7	Titan es
	5.5	Te dn
	5.5	Titan Sh.
	7.5	Te en
	7.7	Titan c 8″ 4s ? Transit
	8.8	Mi en
	9.5	En en
	10.6	Titan bs
25	2.2 am	Mi es
	2.4	Titan as
	1.6 pm	Di Ecl. D
	2.0	En as
	2.5	Te Sh
	4.1	Te bs
	5.2	Di dn
	5.3	Rh es
	6.1	Te as
	7.4	Di en
	7.4	Mi en
	7.9	Rh ds
Feb. 1892.		
25	9.3 pm	Rh Sh
	11.8	Rh bs
26	12.1 am	En an
	12.8	Mi es
	2.3	Rh as
	2.8 pm	Te dn
	4 5	En es
	4.8	Te en
	6.0	Mi en
	8.5	Di es
	10.7	Di ds
	10.9	En as
	11.4	Mi es
27	12.1 am	Di Sh
	2.0	Di bs
	4.2	Di as
	1.4 pm	Te bs
	3 3	En en
	3.4	Te as
	4.6	Mi en
	10.0	Mi es
	11.5	Rh an
28	1.4 am	En es
	1.6	Rh Ecl. D
	3.9	Mi as
	5.4	Di an
	5 9	Rh dn
	1.0 pm	Di en
	2.1	Te en
	3.2	Mi en
	5 8	En an
	8.6	Mi es
29	12 2 am	En en
	2.5	Mi as
	5.8	Te es
	2 2 pm	Di es
	4 4	Di ds
	4.6	En an
	5.8	Di Sh
	7.2	Mi es
	7.7	Di bs
	9.9	Di as
Mar.		
1	1.2 am	Mi as
	2 7	En an
	4.5	Te an
	5.7	Rh es
	12.3 pm	Te Ecl. D

Phases and Aspects of the Moon.

			Central Time. h m
First Quarter	Mar.	5	1 14 P. M.
Full Moon	"	13	6 55 A. M.
Apogee	"	15	3 42 P. M.
Last Quarter	"	21	11 16 A. M.
New Moon	"	28	7 18 "
Perigee	"	28	4 00 P. M.

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean. T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration h m
March. 4...	υ^1 Tauri	5	11 48	93	12 41	254	0 53
4...	υ^2 Tauri	6	12 15	59	13 02	288	0 47
8...	λ Cancri	6	12 28	100	13 33	304	1 05
14...	$\varkappa$ Virginis	6	11 06	161	12 16	277	1 10
15...	*m* Virginis	5	9 52	117	11 04	315	1 08
15...	B.A.C. 4591	6	14 34	99	15 50	335	1 16
22...	ω Sagittarii	5	17 03	38	17 58	312	0 55

List of Binary Stars and Test Objects for Small Telescopes for February and March.

No.	Name.	R. A. 1890. h	m	Decl. 1890. °	′	Position Angle. °	Distance. ″	Magnitude.
1	OΣ 165, 45 Geminorum	7	02.1	+16	07	50	3.5	5 ; 11
2	Σ 1037		06.0	+27	25	305	1.3	7 ; 7
3	Σ 170		12.1	+ 9	30	110	1.5	7 ; 7
4	Σ 1066, δ Geminorum		13.6	+22	11	205	7.0	3 ; 8
5	Σ 1110, Castor AB		27.6	+32	08	230	5.7	3 ; 3.5
	AC					165	73.	; 11
6	OΣ 182		47.2	+ 3	40	30	1.1	7 ; 7.5
7	OΣ 186	7	56.6	+26	36	75	0.7	7 ; 8
8	Σ 1186, 11 Cancri	8	02.1	+27	48	215	3.2	7 ; 10
9	Σ 1196, ζ Cancri AB		06.0	+17	58	30	1.2	5 ; 5.7
	AB-C					120	5.0	; 5.5
10	OΣ 193		22.	+33	55	295	14.0	7 ; 11
11	Σ 1273		41.1	+ 6	49	225	3.2	4 ; 8
12	Σ 1291, σ^2 Cancri		47.7	+30	59	330	1.4	6 ; 6.5
13	OΣ 196, ι Urs. Maj	8	51.8	+48	28	5	9.5	3 ; 10
14	Σ 1306	9	00.5	+67	35	240	3.0	5 ; 8
15	Σ 1334		12.0	+37	16	235	2.9	4 ; 7
16	Σ 1356, ω Leonis		22.6	+ 9	32	100	0.7	6 ; 7
17	Σ 1377, 161 Sextantis		37.8	+ 3	08	135	3.3	8 ; 11
18	OΣ 210	9	55.7	+46	54	270	0.8	7 ; 8
19	OΣ 215	10	10.3	+18	17	215	0.7	7 ; 7
20	OΣ 523, 39 Leonis		11.2	+23	39	300	6.7	6 ; 11
21	Σ 1424		14.0	+20	23	115	3.6	2 ; 4
22	Σ 1457		33.1	+ 6	18	320	1.2	7 ; 8
23	OΣ 224		34.0	+ 9	25	315	0.5	7 ; 9
24	OΣ 228		41.3	+23	09	200	0.4	7 ; 8
25	Σ 1504	10	59.8	+ 4	14	285	1.1	7 ; 7
26	Σ 1523	11	12.3	+32	10	200	1.7	4 ; 5
27	Σ 1536, ι Leonis		18.3	+11	09	60	2.5	4 ; 7
28	OΣ 236		30	+66	57	215	2.7	7 , 11
29	OΣ 237	11	33.1	+41	45	275	1.0	7 ; 9
30	OΣ 249 AB	12	18.7	+54	46	300	0.5	7 ; 8
	AB-C					150	13.0	11

In response to frequent requests of some of our subscribers we give this list of double stars which cross the meridian during the evening hours of February and March. Most of the stars in the list are binaries, which need to be measured frequently, and many of them will afford good tests for the quality of telescopes of 4 inches or more aperture.

Nos. 2, 3, 6, 12, 22, 25, are good tests of the separating power of a 4 or 5-inch objective. Nos. 7, 16, 18, 19, will serve the same purpose for a 6 or 7-inch glass, and Nos. 23, 24, and 30 for larger glasses. As tests of definition Nos. 4, 11, 14, 15 and 21 are good objects. The fainter components of 10, 13, 17, 20, 28 and 30 may be used to test the light-gathering or space-penetrating power of a telescope.

Occultations of Stars by the Planets.

In *Astronomische Nachrichten* No. 3073, Dr. Berberich gives a list of near approaches and possible occultations of stars by the planets during the year 1892. As it is important that these should be observed as generally as possible we will give the list for each month. Most of the stars are so faint as to be beyond the reach of small telescopes when in the vicinity of the planet, yet many may be observed possibly with telescopes of as low as 4 inches aperture. In these observations one should note the exact time, standard or local, corrected for error of time-piece, of the disappearance and reappearance of the star, as well as any change in appearance of the star as it passes behind the planet.

STARS NEAR VENUS.

Date	Central Time of Conjunction. h m	Diff. of Decl. ″	Maximum Duration. m	Magnitude of Star.
Feb. 6	3 56 P. M.	− 58	4.4	7.8
8	12 43 A. M.	− 60	4.5	9.3
10	3 14 A. M.	+ 27	4.5	9.3
18	12 58 A. M.	− 20	4.7	9.0
20	10 47 A. M.	+ 73	4.8	8 9
22	12 04 A. M.	− 56	4.8	7.3
28	5 06 P. M.	+ 49	5.0	9.4
Mar. 7	4 14 A. M.	− 39	5.3	9.0
12	11 51 P. M.	− 79	5.6	9.0
12	11 59 P. M.	+ 87	5.6	9.0
21	11 18 A. M.	+ 57	6.0	8.9
23	5 26 A. M.	− 22	6.1	6.0
28	12 19 P. M.	+ 6	6.5	8.3

Two Minor Planets Discovered by Photography. Two planets were discovered photographically at Heidelberg December 22. They were observed at Vienna, Dec. 31 in the following positions:

Dec. 31.3550 GR. M. T.; R. A. 6^h 37^m 01.2^s; Decl. + 24° 50′ 22″
Dec. 31.4806 " " " 6 48 48.2^s; " + 18 38 28
Daily motion of the first —1^m 24^s and + 19′
Daily motion of the second —1 00^s and + 2′

The latter of these was found to be Sapientia (275).

New Minor Planet No. (324). A planet of the 11th magnitude was discovered at Heidelberg photographically January 20.2491 in R. A. 3^h 50^m 06.1^s; Decl. + 22° 17′ 34″. Daily motion 12^s eastward and 2′ northward.

Brilliant Meteor. Mr. E. M. Wilson observed a brilliant meteor Dec. 19, 1891, at 8:18 P. M. central time, one mile east of Onslow, Jones county, Iowa. It arose in the northeast, from behind a bank of clouds, near σ or ρ (?) of Ursa Major, crossed a little east of the zenith, between Capella and the Pleiades, toward the southwest, and vanished at an altitude of about 45°, not far from Jupiter. Its motion was slow at first sight, faster as it passed the zenith, and its brightness exceeded that of Jupiter. Its train remaned in view a second or two. No explosions observed, or heard.

Almanaque Nautico Para el Ano 1892 is received. It is a large volume of 591 pages. It is in the usual form and contains about the usual matter of government publications of the kind. It is the first we have seen from Spain.

COMET NOTES.

The Tempel-Swift periodic comet is now too faint for all but the largest telescopes. Mr. Barnard writes that he is still observing it. At Goodsell Observatory we looked for it last on the night of Jan. 13, but the temperature was 13° below zero and seeing poor, so that the comet was not seen. On the same night Wolf's comet was an easy object with the 16-inch and barely visible in the 5-inch finder. With the large telescope Wolf's comet had a sharp stellar nucleus of about the 12 magnitude, dense coma of about 2′ diameter, and short, faint brush of tail directed almost due north. During March this comet will pass through the familiar constellation Orion. March 1 it will be about 4° north and a little west of Rigel, near the star β Eridani. From the 23rd to the 26th it will be passing through the belt of Orion between the stars ε and ζ. There is a nebula near ζ, the lower of the three bright stars in the belt, which must not be mistaken for the comet.

No ephemeris has yet reached us for Tempel's comet which is due at perihelion in the latter part of February. Neither Winnecke's comet nor Brooks' comet (1886 IV) have yet been picked up. We continue below the search ephemeris for the latter from Astr. Nach. No. 3064.

Search Ephemeris for Comet Brooks, 1886 IV.

[See also p. 85].

1892.	Perihelion March 31. α	δ	Light	Perihelion April 30. α	δ	Light
	h m	° ′		h m	° ′	
Mar. 1	16 52.9	− 14 34	0.32	15 02.1	+ 2 35	0.48
11	17 28.1	− 17 14	0.38	15 24.8	+ 0 32	0.66
21	18 03.8	− 19 44	0.43	15 47.3	− 2 01	0.93
31	18 39.3	− 22 04	0.48	16 09.4	− 5 15	1.37

	Perihelion May 30. α	δ	Light	Perihelion June 29. α	δ	Light
	h m	° ′		h m	° ′	
Mar. 1	12 45.3	+ 24 48	0.39	10 36.8	+ 39 24	0.20
11	12 43.8	+ 25 29	0.53	10 24.9	+ 39 00	0.22
21	12 38.7	+ 25 58	0.71	10 14.3	+ 37 52	0.25
31	12 31.8	+ 25 45	0.90	10 06.6	+ 36 02	0.28

Next Apparition of Wolf's Comet. In the last number (253) of the *Astronomical Journal* Dr. Berberich gives the elements of Wolf's comet from the observations of its second apparition (the present) as follows:

Epoch 1891 Sept. 8.0 Berlin M. T.

$$\begin{aligned} M &= 0^\circ\ 39'\ 12.4'' \\ \omega &= 172\ \ 48\ \ 28.0 \\ \Omega &= 206\ \ 21\ \ 27.5 \\ i &= 25\ \ 14\ \ 37.6 \\ \varphi &= 33\ \ 51\ \ 25.7 \\ \mu &= 520.2536'' \\ \log a &= 0.5558610 \end{aligned}$$

(ω, Ω, i: 1890.0)

These elements represent the observations of 1884 very satisfactorily. The next return will be in 1898, perihelion taking place June 30. The comet will then be observable during many months. The later returns will be unfavorable for observations. In 1922-23 the comet will approach so near to Jupiter as to have its orbit greatly changed and perhaps be lost to sight forever.

Ephemeris of Winnecke's Periodic Comet.

(Continued from page 86.)

	App R. A. h m s	App. Decl. ° ′	log r	log Δ	$\frac{1}{r^2\Delta^2}$
March. 1	12 52 36	+23 47.8			
2	52 24	24 09.6	0.2689	9.9749	0.325
3	52 10	24 31.8			
4	51 53	24 54.4			
5	51 34	25 17.2			
6	51 12	25 40.4	0.2596	9.9521	0.377
7	50 48	26 03.9			
8	50 21	26 27.7			
9	49 52	26 51.7			
10	49 20	27 16.0	0.2501	9.9298	0.437
11	48 45	27 40.5			
12	48 08	28 05.3			
13	47 28	28 30.2			
14	46 45	28 55.4	0.2403	9.9080	0.505
15	45 60	29 20.7			
16	45 11	29 46.2			
17	44 20	30 11.7			
18	43 26	30 27.4	0.2302	9.8871	0.583
19	42 29	31 03.1			
20	41 30	31 28.8			
21	40 27	31 54.6			
22	39 22	32 20.3	0.2198	9.8670	0.607
23	38 14	32 46.0			
24	37 03	33 11.7			
25	35 49	33 37.2			
26	34 33	34 02.5	0.2092	9.8480	0.769
27	33 14	34 27.7			
28	31 52	34 52.7			
29	30 28	35 17.4			
30	29 01	35 41.9	0.1982	9.8300	0.878
31	27 32	36 06.0			
Apr. 1	26 00	36 29.9			
2	24 27	36 53.3			
3	22 51	37 16.4	0.1870	9.8130	1.000
4	21 13	37 39.0			
5	19 33	38 01.2			
6	17 52	38 23.0			
7	16 09	38 44.2	0.1754	9.7970	1.135
8	14 24	39 05.0			
9	12 38	39 25.2			
10	10 51	39 44.8			
11	09 02	40 03.9	0.1636	9.7819	1.285
12	07 13	40 22.3			
13	05 22	40 40.2			
14	03 31	40 57.4			
15	12 01 40	+41 14.0	0.1514	9.7675	1.453

Ephemeris of Comet 1891 (Wolf's Periodic Comet.)

(From Astr. Nachr. No. 3071)

Berlin Midnight.	App. R. A. h m s	App. Decl. ° ′	log r	log Δ
Feb. 15	4 42 49	− 7 21.0		
16	43 53	7 10.9	0.3510	0.2705
17	44 58	7 00.9		
18	46 04	6 50.8	0.3533	0.2777
19	47 11	6 40.9		
20	48 18	6 31.0	0.3556	0.2848
21	49 27	6 21.1		
22	4 50 36	− 6 11.3	0.3579	0.2919

Berlin Midnight.	App. R. A. h	m	s	App. Decl. °	′	log r	log Δ
Feb. 23	4	51	45	— 6	01.6		
24		52	56	5	51.9	0.3602	0.2989
25		54	07	5	42.3		
26		55	19	5	32.7	0.3625	0.3058
27		56	32	5	23.2		
28		57	45	5	13.8	0.3648	0.3127
29	4	58	59	5	04.5		
March. 1	5	00	13	4	55.2	0.3670	0.3194
2		01	29	4	46.0		
3		02	45	4	36.9	0.3693	0.3261
4		04	01	4	27.8		
5		05	18	4	18.9	0.3715	0.3328
6		06	36	4	10.0		
7		07	54	4	01.2	0.3737	0.3393
8		09	13	3	52.6		
9		10	32	3	44.0	0.3760	0.3458
10		11	52	3	35.4		
11		13	12	3	27.0	0.3782	0.3521
12		14	33	3	18.7		
13		15	54	3	10.5	0.3804	0.3584
14		17	16	3	02.3		
15		18	38	2	54.3	0.3826	0.3647
16		20	00	2	46.4		
17		21	23	2	38.5	0.3848	0.3708
18		22	47	2	30.8		
19		24	11	2	23.2	0.3869	0.3769
20		25	35	2	15.6		
21		26	60	2	08.2	0.3891	0.3829
22		28	25	2	00.9		
23		29	50	1	53.6	0.3912	0.3888
24		31	16	1	46.5		
25		32	42	1	39.5	0.3934	0.3947
26		34	08	1	32.6		
27		35	35	1	25.8	0.3955	0.4004
28		37	02	1	19.1		
29		38	30	1	12.5	0.3976	0.4061
30		39	57	1	06.0		
31	5	41	25	— 0	59.6	0.3997	0.4117

Comets and Meteors. You recently inserted an extract from a letter of mine to the effect that, judging from their orbits, meteors appeared to belong to the solar system instead of being visitors from external space. May I now add that the comets with which meteor-showers have hitherto been connected are all elliptic or periodical comets. It would thus seem that a parabolic or hyperbolic comet which passes but once through the Solar System, fails to pick up any meteor train worth mentioning, while on the other hand, periodic comets which have circled round the Sun for ages appear to possess these appendages whenever they approach sufficiently near us to afford a test. That comets generally are visitors from outer space is confirmed by some investigations which I lately made as to their aphelia and which I hope to publish shortly. But meteor-comets have at all events been domiciled with us for a considerable time.

W. H. S. MONCK.

A Clark Three-inch Telescope in the possession of one of our subscribers can be purchased at a reasonable price. It is said to be in first-rate condition; eyepieces are 32, 80, 135 and 220 diameters respectively; ordinary and solar diagonals, plain equatorial mounting, without circles or tripod. The head has been used on a fixed wooden stand. A larger instrument has been procured, and hence this one is offered for sale.

NEWS AND NOTES.

It is gratifying to announce that our subscription list has not fallen off seriously since the advance in price, as we feared it might do, but, on the contrary, it has gained a little during the last month, so that, at present, the number of actual subscribers is a little larger than it has been at any previous time during the ten years of history distinctively belonging to THE MESSENGER.

As usual there is a considerable number of subscribers who are yet delinquent for a portion of 1891. It is respectfully and urgently asked that *every* such one promptly notify the publisher that *continuance* or *discontinuance* is desired, so that the publication under the new form may be sent only to those desiring it. If any names are dropped from our books it will be because subscriptions have not been renewed, or continuance of the same ordered.

If it were our custom to print the good things that our many readers say of us in our new dress and form, we could easily fill considerable space; but it seems best to adhere to our old plan in this particular; so we most heartily and cordially thank our many friends for their well wishes, congratulations, and substantial help, that so many have already rendered us in promptly renewing subscriptions, and offering unexpected aid in other ways.

Light Curve of the Eclipse of Japetus. By referring to the figure on page 120 of Mr. Barnard's article it will readily be understood that the vertical column of figures means the sidereal times of individual estimations, while the horizontal column above gives the difference of light between *Enceladus* and *Tethys* in steps of one-tenth each during the eclipse. Beginning with the emergence from shadow of ball of Saturn the curve indicates the variation of light till the satellite passes into the shadow of the crape ring, and then it falls off rapidly until entering the shadow of the bright ring which was fully as dense as the shadow of the ball itself.

Delicate Refractometer. Mr. J. A. Brashear of Allegheny, Pa., has, very recently, completed the optical surfaces for a new refractometer for Professor A. A. Michelson, who is to determine the value of the standard meter of the International Bureau at Brentueil, in France. These surfaces show work of the most delicately accurate kind. The limiting error is said to be less than one-millionth of an inch. Still Mr. Brashear is conscious of very, very small existing errors, which it seems next to impossible to remove.

Neue Annalen der K. Sternwarte in Bogenhausen bei Munchen. This publication was prepared under the direction of Hugo Seeliger, Director of the Royal Observatory, and contains the results of seven different kinds of work. The first is a catalogue of 13200 stars whose mean places are for the epoch of 1880 and were observed and reduced by Dr. Julius Bauschinger.

2. Neue Beobachtung und Ausmessung des Sternhaufens 38h Persei, von Dr. K. Oertel; mit 2 Taflen.
3. Die Vertheilung der in beiden Durchmusterung enthaltenen Sterne am Himmel von dem Unterzeichnten.
4. Ueber die Biegung von Meridianfernrohren von Dr. J. Bauschinger, mit 1 Taflen.

These and other papers are of special value to the astronomer.

Since our last issue the sad news comes across the water of the death of two of England's great men; Sir George B. Airy, formerly Astronomer Royal, and Professor J. C. Adams of Cambridge Observatory; the former occurring Jan. 2 and the latter Jan. 22. In another issue of this publication will be given brief accounts of the lives of these scholarly men.

A Remarkable Aurora. The Auroral display upon the evening of Tuesday, Jan. 5, as viewed from a suburb of Boston, was one of exceeding beauty, and often of marked brilliancy. At 7:30 P. M., an arched *bank* of auroral light extended from N.E. to N.W., rising at the north point 20° above the horizon. At this time there was no other display except in the N. N.E. at an altitude of 30°; here an solated bright area, about 15° vertically by 10° horizontally, was fairly permanent, and at times, faintly connected with the underlying bank. The sky was not observed again until about 10 P. M., at which time the aurora had assumed magnificent proportions. At times the sky was almost completely covered from E. S.E. through N. to W. S.W., and when most extended, reached south of the zenith even to the "belt" of *Orion*. A variety of tints was very noticeable both upon the same areas in succession, and upon different areas simultaneously. The colors noted were yellow, pale green, olive green and bluish. At times while one color extended over an area of distinct boundary, another color would completely pervade the adjoining regions. There were comparatively few streamers, the display being mostly in extended sheets and broken waves. There was relatively little smooth upward flow of the waves, but a marked pulsation, the waves rising and falling as they advanced toward the zenith. In one instance a wave seemed to "see-saw" as it ascended; the right and left sides advancing alternately while the general form remained that of a parallelogram hinged at each vertex. One figure which appeared in the zenith was of a character to produce consternation among a superstitious people. At a time when the sky near the zenith was essentially clear, the blue presenting a beautiful contrast with the auroral light to the north, east, and west; there suddenly appeared in the midst of this clear area a form suggesting at once an immense eagle with spread pinions, flying directly southward. The wings were perhaps 15° long, yellow, and exceedingly brilliant.* This form remained approximately permanent for at least three minutes, and soon after its appearance, the general display was extended much farther southward.

There was some haze upon the sky during most of the evening, and there were a few light, high-running clouds. J. B. C.

Measures of the Faint Double Star (H 2948) between β^1 and β^2 Capricorni. The faint pair, H 2948, which lies a little north of the line joining β^1 and β^2 Capricorni, has been often referred to in popular articles as a light-test for moderate apertures. For this reason, and the further reason that it had never been measured, I took occasion to measure it on two nights, after having measured the close pair, β^1 Capricorni, discovered by Barnard in 1883.

As a double star, H 2948 must be regarded a failure. The distance between the stars is much too great to make any physical connection between stars of this magnitude in the least probable. It first appears in Herschel's *Fifth Catalogue* (1830-31) with a single measure of the angle, and the following note:

"A very minute star, forming an obtuse-angled triangle with β^1 and β^2 Capricorni. Pos. from $\beta^1 = 63°.4$; from $\beta^2 = 296.°0$. It is one of the most minute

* Being as bright as any area observed that evening, and far surpassing in brilliancy most of the waves and streamers.

and delicate double stars I have seen; and being so easily found, is an excellent test-object."

There is an earlier estimate of the angle, distance and magnitudes in Herschel's *Seventh Catalogue* (observations made 1823 to 1828). Concerning this pair he says in the remarks in the Fifth Catalogue:

"I have sometimes been asked for test-objects to try at once the light and distinctness of a telescope under high powers. In such cases it is desirable to select objects which can be certainly found without the possibility of mistake; and in this view I would point out the small double star accompanying β^1 and β^2 Capricorni, (H 2948), or the small double companion of β Equulei (H 2023) as very well adapted for the purpose. A telescope which will show the former of these objects distinctly double, I have no hesitation in saying, must be competent to the most difficult work which any ordinary observer is likely to task it with. No telescope, I ought to add, can be expected to show the satellites of *Uranus* (at least in the present low situation of the planet in the ecliptic) which will not stand this test."

This little pair is by no means as difficult as one would be led to expect from the foregoing remarks, and from the magnitudes (17 and 18) which Herschel gave to the components. I found it very plain with the 9.4-inch Clark refractor at Hanover in 1874, and as one star it was always easy enough with my 6-inch, but that aperture perhaps could not be said to show it fairly double. But at most it is only a light-test. To form a test for the definition of an objective, the distance would of course have to be reduced to at least one-fifth of that between these stars.

I give in tabulated form the observations of Herschel, and my recent measures with the 36-inch:

1825 ±	120° ±	8″ ±	15......16	H 1η
1830 ±	322.2	3 ±	17......18	H 1η
1891.66	322.3	6.42	13......13.4	β 2η

I measured also the position of this pair from the following of the two bright stars as follows:

β^2 Capricorni and H 2948.

1891.655	294°.1	111″.75
.673	294 .0	111 .66
1891.66	294°.0	111″.70

Obviously there is no evidence of any change either in the components of H 2948, or in their position with reference to β^2 Capricorni. No change could be expected except such as might be the result of some proper motion.

Mt. Hamilton, Dec. 21. S. W. BURNHAM.

Burnham's Measures of Planetary Nebulæ. [During his regular double star work with the 36-inch equatorial of the Lick Observatory, Mr. Burnham has given some attention to the more interesting nebulæ, and incidentally to a few of the Herschel planetary nebulæ. On examining the records of the best observers, he was surprised to find that almost nothing had been done in the way of taking careful micrometrical measures to determine the places even of the brighter of the planetary nebulæ. This seemed to him, very naturally, a most useful field of work, as a means of determining whether or not these bodies have proper motion. There can be no doubt, but that, in time, careful work of this kind would reveal important results. The central star in this class of nebulæ is, of course, used as the point of reference in measurement, and this is so generally found in planetary nebulæ that it is suggested as a criterion for classification of these bodies. Some of these stars are very faint and can only be seen with telescopes of large aperture, and, in a few instances, the large object-glass of the 36-inch equatorial furnishes none too much light for their accurate measurement with the micrometer. Mr. Burnham has used Dreyer's General Catalogue in making up his observing lists, and he says he has examined Nos. 934, 2440, 2452, 4107, 5144 and 6210, and found them more or less lacking in the characteristics of planetary nebulæ. He thinks they properly belong to a much larger and less interesting

class of objects which would be briefly described as small circular patches of nebulosity. He also speaks of the so-called "stellar" nebulæ discovered by Pickering, Swift and others. "These are all, so far as I have examined them, very small, bright, round nebulæ, which in a small instrument would resemble stars slightly out of focus, but do not appear to come within the planetary class."

In speaking of the central star in this class of nebulæ, Mr. Burnham says "there can be no doubt that these central stars are, in some way associated with the nebulæ themselves, and that any change in the positions of these stars will be accompanied by a corresponding drift in space of the nebulæ. Of the thousands of nebulae now known, these examples of the planetary class, with a few exceptions possibly among very minute nebulae, are the only ones where any proper motion could be detected within any reasonable time. For this reason there is no reliable evidence yet of the change in position of any nebulae in the heavens."

It is further claimed that there is no apparent reason why the nebulae should not be distributed in space as the stars are, nor why they should not have proper motion like the stars. A few measures during a brief period of years will certainly reveal small changes of place, even if these be in the form of slight annual variation only. The detailed descriptions of thirty or more of these planetary nebulae recently observed by Mr. Burnham add large and new interest to this field of research.

Aurora Observations. We take pleasure in giving the following letter from Mr. M. A. Veeder of Lyons, N. Y., which bore date January 16.

"The note in ASTRONOMY AND ASTRO-PHYSICS in regard to observing auroras is being heard from, and I am much obliged for your inserting it.

"In sending out blanks, etc., during December I generally called attention to the fact that a series of recurrences of the aurora at 27¼-day intervals would probably begin on January 5th. This expectation has been fully realized by the appearance of an unusually brilliant aurora on that date. It would seem from this that the next few months are likely to be especially favorable for observations of this character. Already interesting results are being secured from the plan of observation that has been organized. By noting the time of each observation and recording the absence as well as the presence of the aurora it has become evident that an aurora may be present at southern stations when absent at those directly northward. This is something different from what we would naturally expect, and perhaps its explanation may become apparent in the course of the research."

From Dr. Wilson's notes we give the description of the aurora that was seen at Goodsell Observatory Jan. 5, as follows:

"Remarkable aurora extending from 80° west to 100° east of north point; at times reaching 10° south of the zenith. Noticed first at 6 o'clock P. M., in light of the moon nearly half full. Very few streamers, but large oval, cloud-like masses changing rapidly. Motion from east to west. Dark cloud-like arch about 15° high at 7 o'clock P. M. At 9 P. M. arch 45° high surmounted by fine arch of short, bright streamers changing rapidly, the whole lasting only a few minutes, then changing to the oblong bright clouds."

Variation of Latitude. Recently various scientific journals have been discussing the question of the variation of latitude. The articles that have appeared during the last two months in the *Astronomical Journal* are especially noteworthy. In No. 248, Mr. S. C. Chandler, of Cambridge, calls attention to a series of observations made with the Almucantar, six years ago, which "exhibited a decided and curious progression throughout," the earlier values of the difference between computation and observation being positive while the later ones were negative. These observations extended from November, 1884, to April, 1885, and the range was about four-tenths of a second. The observations were continued to the end of June of the same year, and a negative maximum was found about May 1, while from the previous observations of May to Nov., 1884, a positive maximum appeared about Sept. 1, showing a range of about $0''.7$, "with a half period of about seven months." This discussion was based on the observations of stars between $-5°$ and $+5°$ declination. Another study of stars between $+5°$ and $+50°$ in declination gave an exactly corresponding variation of latitude both in direction and range. In this connection Mr. Chandler mentions the fact, that Dr. Küstner in his determination of aberration from a series of observations made at the same time and published in 1888, noticed similar

anomalies, and, tha twork at Berlin, Prague, Potsdam and Pulkowa indicates a change in range and period that surprisingly accords with results already named.

In Nos. 249 and 250 of the *Astronomical Journal*, Mr. Chandler gives a detailed discussion of the observations before referred to, and others similar to them, from which he reaches a general result in this preliminary discussion, showing "a revolution of the Earth's pole, in a period of 427 days, from west to east with a radius of 30 feet measured at the Earth's surface. Assuming provisionally for the purpose of statement, that this is a motion of the north pole of the principal axis of inertia, about the axis of rotation, the direction of the former from the latter lay towards the Greenwich meridian about the beginning of the year 1890. This, with a period of 427 days, will serve to fix approximately the relative positions of the axes at any other time for any given meridian. It is not possible at this stage of the investigation to be more precise, as there are facts which appear to show that the rotation is not a perfectly uniform one, but is subject to secular change, and perhaps irregularities within brief spaces of time."

Readers who wish to make a study of the evidence of these important conclusions should refer to the papers mentioned above.

Periodic and Secular Variations of the Latitude. Professor George C. Comstock, Wasburn Observatory, Madison, Wis., has also published a very suggestive paper, in No. 252 of the *Astronomical Journal*, on the Relation of the Periodic and Secular Variations of the Latitude. In this article he calls attention to a paper which he published in the *American Journal of Science*, December, 1891, and which gives a discussion of the data furnished by observations at Pulkowa, Koenigsberg, Washington and Madison, which appears to show a progressive motion of the terrestrial pole whose effect on the latitudes of these Observatories is represented by the expression

$$\varphi - \varphi_0 + 0''.044 \cos(\lambda - 69^\circ)(t - t_0),$$

in which the longitudes, λ, are reckoned from the meridian of Greenwich, and the unit of t is a year.

Mr. Comstock does not offer any hypothesis for the cause of secular change of latitudes, but prefers to treat it at present as a phenomenon requiring confirmation. Its existence is legitimately assumed, as a working hypothesis, and its relation to other phenomena may be discussed. He thinks that the existence of a secular term in the latitudes will necessarily produce a periodic term also, for by virtue of its progressive motion, the instantaneous axis of rotation of the Earth is moved away from the principal axis of inertia. "The forces developed by the separation of these axes will tend to re-adjust the figure of the Earth so as to bring these axes again into coincidence;" but this can not be done instantly, "and the axis of figure will lag behind the axis of rotation, by an amount depending, in great part, upon the modulus of the Earth's rigidity, thus producing the theoretical periodic motion of the pole associated with Euler's name"

We are sorry we have not before us Professor Newcomb's article on this theme which was published in the *Astronomical Journal*, No. 251, so as to refer to it more fully in this connection. Professor Comstock refers to that paper and says: "Professor Newcomb has indicated that the imperfect rigidity of the Earth may produce a very appreciable lengthening of this period, and he is inclined to attribute to this cause alone the total excess of the period found by Mr. Chandler over the value 306 days which would obtain in a rigid Earth." But Professor Comstock thinks that imperfect rigidity of the Earth would not explain the anomalous variations of amplitude and period of inequality found by Mr. Chandler, chiefly because we are constrained to regard the rigidity of the Earth as practically constant, at least, for short periods of time, but he does think that both can be explained by taking into the account the secular change of the position of the pole. The proofs for this position are given and the results are in striking conformity with the empirical results found by Mr. Chandler. Professor Comstock further says: "That all the characteristic features of the periodic term detected by Mr. Chandler seem to admit of explanation through the assumed nutation and secular variation of the pole. Any secular variation of the position of the pole will produce a periodic variation of latitudes. If the secular variation is a uniform motion along a great circle, the periodic term will be of constant amplitude and length, but, if the secular variation itself contains periodic terms, they will manifest their presence through irregularities in the periodic terms of the latitude." Plans for further study of this question are suggested.